SCIENCE FOR THE HOME

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BY

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INTRODUCTION

SCIENCE LENDS A HAND

THERE was a time, not very long ago, when Science, more particularly chemistry and physics, was considered as an academic study with little or no connection with the lives of ordinary people. That day has gone. The average man now realizes that Science is not an airy, abstract affair, but a thing of vital importance to him as an individual, or as a member of any civilized community. He knows, when crossing a bridge, that he is safe because engineers have calculated or tested the stresses and strains; that when he switches on his wireless he will hear speech or music because scientists have expended millions of hours in experimenting to attain these results.

But still I doubt whether the average man, and perhaps even more, the average woman, realizes how intimately Science enters into every phase of life at home. So I have tried to show that the modern home is "scientific," not necessarily in the sense that it is technically conducted, but in the fact that it owes everything to Science. Many features of a

modern house may appear the same as those of the homes of three hundred years ago. Yet in truth everything has been changed by the development of Science. Although the architecture may be "Tudor," it is carried out with materials made by twentieth-century machines. Chairs, tables, curtains, and equipment may be found in the home of to-day in types resembling the products of the past two centuries; but the methods of manufacture have changed enormously. Even the contents of the kitchen have changed. It is difficult to realize, for example, that ordinary sugar was almost unknown in the Middle Ages. Vanilla and many other essences are of comparatively recent origin. The housewife of olden days had no washing soda to help her scour her dishes or dissolve grease from cloths. She had no tinned foods.

In the last fifty years, the greatest change has been the way in which Science has made available for all what was before only within reach of the few. Carpets are no longer a luxury. Ingenious machinery employs tens of thousands to bring good and beautiful furniture into the poorest homes. The common chemicals we use, salt, sugar, or soda, are ridiculously cheap, especially when it is remembered that the sugar is 99.9 per cent. pure and that the salt has minute quantities of other chemicals deliberately added to keep it dry.

It is difficult to realize how recent are many of the things we now take for granted in every home. Linoleum could not have been found in any house

before 1864. Constant hot and cold water would have been wasted one hundred years ago, for our ancestors had little belief in baths. When King Edward VII. first went to Balmoral, there were only one or two bathrooms in the entire establishment. A hundred years ago the beautiful dyes that give us an endless variety of cloths for curtains and upholstery were undiscovered. Cheap carpets were unknown, for they had all to be hand-made. The "knocker-up" was the crude alarm clock that woke the workers of the first decades of the industrial revolution.

There is another aspect of Science in the home, which is very important indeed. In the average house, on any day, enough "scientific experiments" are conducted to put a laboratory to shame. It is a common mistake to think that experiments are made only in laboratories by learned scientists. Perhaps these are not, strictly, new to the home, for the results ought already to be known, but they are experiments in the schoolboy sense. We may often be amused at the elaborate apparatus that a science master will set up to demonstrate some scientific law to his class, when all the time the same law in action has been under their noses since they were born. Latent heat, magnetism, the expansion of gases, the conservation of matter—these and a hundred scientific principles can be illustrated in the ordinary work of daily life without special apparatus. We make use of such principles all day in refrigerating our food, cleaning a room, burning fires, or preparing a meal.

CHAPTER I

HOW THE HOUSE WAS BUILT

So many materials go to the making of a house, and so few are at all uncommon, that it is rare for any one to worry about their history or origin. It may seem that the houses of to-day are very much like those of four centuries ago and that Science has brought but slight changes to the art of building. This is quite incorrect. By the introduction of scientific methods the quality of bricks, mortar, and every conceivable material has been improved or standardized. But for the invention of automatic machinery the "housing boom" which has marked the post-war years would have been quite impossible, and economic slum clearance must have been indefinitely postponed.

Wood and stone were probably the first materials used for building; we still use them to-day, although in a different form and in limited quantities. Wood is now generally only employed for rafters, door-frames, or similar parts, and even in these cases steel might be superior but for its greater cost. Wood houses often suffer too much from the weather and carry a heavy risk from fire, but in the main, wood and stone have given place to other materials in Britain because we have exhausted the most con-

venient natural supplies. Large cities are now seldom near to any forestry. The wooden frames used for building modern houses are often made by machinery in huge quantities so that costs can be reduced to an absolute minimum.

Surprising as it seems, the most important material in most houses is still bricks. Archæologists have found that bricks were used in the earliest civilizations, even 10,000 years B.C., although these were very different in manufacture from those we employ to-day. Bricks found at Babylon were three inches thick by about a foot square, but unlike most of these ancient examples they had been burned and were strong enough after thousands of years to be used for building new houses. Bricks were used in England by the Romans, but the art died out for some centuries, to be revived later and to come into its own again with the introduction of machinery during the last century.

What is a brick? You will probably answer, quite rightly, that it is baked clay. But when we remember that the clay itself is composed of minute fragments of rocks, it is easy to realize that bricks are stone which man has put together. The minute fragments of rock were worn away by water, frost, and wind; but man-made bricks are able to withstand weather or temperatures which would soon have dissolved the original rocks. Fire-bricks will bear enormous temperatures without being harmed, whereas the rocks from which the clay was made would have cracked and powdered in a few hours.

Bricks to-day are made in standard sizes, although of many different qualities. Standardization is necessary, not only for appearance but also for mass production. Suitable clay for brick-making can be found in most parts of the country, brickworks being usually erected near to large towns where there is a demand for the products. The clay as it is dug out is not in a fit state for moulding. In olden times it was prepared by exposure to the weather for a winter and then trodden by men. Nowadays a machine called a pugmill mixes the clay, which is stirred and cut by rough knives into a mass rather like toothpaste from a tube. Hard clays are first pulverized between rollers above the pugmill and mixed with water. With modern methods it is no longer necessary to have clay that is dug up in plastic form; indeed, a large number of London houses are built with what is called the fletton brick. This is made from a shale found underneath the surface beds of plastic clay, and the bricks are formed by the use of considerable pressure. The first bricks so made were a failure because they crumbled after a time, but it was soon found that by using still greater pressure, satisfactory bricks could be produced.

Originally, the clay that came from the pugmill was moulded by hand to the required shape, and a certain amount of hand moulding is still carried out. In large brickworks, however, the shaping of the bricks is entirely automatic. The exit from the pugmill is a rectangular nozzle, so that the clay comes out in the form of a thick tape having the exact

height and width of the standard brick, which is nine inches by four and a half by three. At regular intervals a knife descends and cuts off a length of this tape, so that a brick is made. The knife is made of wire, which cuts through the clay without sticking. The bricks thus formed pass along a conveyer belt to a press, in which they are squeezed to remove surplus moisture before drying. Formerly, two or three years might be required for drying bricks under a shelter, but this is now accomplished in from three days to three weeks. The first method of artificial drying used was that of passing surplus steam from the boilers over the bricks at night when the works were closed. The more modern plan is to have a drying tunnel through which small trolleys laden with bricks move slowly while a blast of hot air is blown over their surface. This is satisfactory for some clays, but over-costly with others. Some types of brick are first heated in a very moist atmosphere and then dried by air to prevent cracking or warping.

In many cases the bricks used by the early builders soon crumbled under the weather. This was because they were sun-baked and not fire-baked. Houses, indeed, were then very little different from the mud huts of natives. Every brick is now burned, although the methods by which this is done are diversified. In the oldest methods a kiln is used. It is packed with bricks and then fired with wood or coal. In an improved form of kiln, the hot flames are made to travel up the walls and then over the top of the bricks, which are built round in the shape

of a hollow cylinder. The gases are drawn off by a chimney at the bottom. In another principle the fuel is incorporated in the bricks themselves and placed between their layers. A small fire at the bottom of the " clamp " is sufficient to start combustion all through the piles. The " clamps " are sometimes of tremendous size, holding 3,000,000 bricks. It may take six weeks to burn a clamp of this size through every brick.

Two other modern methods of burning are interesting. In one, the burning rooms are placed in series, so devised that the air from one can be drawn into the next chamber by means of dampers, the air from the bricks that are cooling is taken into the rooms where the bricks are being heated, so that no heat is wasted. The dampers are opened or shut so that one room after another becomes the hottest. The process has the advantages that it conserves the heat and is continuous, instead of being intermittent as with kilns or " clamps." In another new process the bricks are packed on trolleys and carried slowly through a tunnel in which they are burned while passing over a furnace. In this case the burning is continuous and very much quicker, the bricks passing in a continuous stream from one end of the tunnel to the other in from one and a half to three days.

Many different kinds of brick are made for different purposes and an immense variety of colours produced. The glaze on some bricks is often obtained by adding salt during firing. In other instances the colouring is due to the clay, as in Staffordshire blue,

or to a mixture of chalk, which gives the bricks a yellowish colour.

Good bricks are of considerable strength, but, as will be appreciated, their strength in a building depends very much upon the mortar that is used for bonding. The " crushing strength " of a brick is reduced by half or more when it is built into a wall with mortar. The science, or art, of the builder and bricklayer is to lay the bricks so as to obtain the greatest strength with the best appearance. The usual way of laying bricks, so that the joins of one row are exactly over the middle of the bricks below, is carried out not only because it looks well but also because it gives the maximum resistance to loading. There are many different ways of bricklaying designed to give various effects, but always the workman has to bear in mind this question of strength. He knows that he will only make a strong wall if the bricks are laid exactly on top of each other, and for this reason he uses his plumb-line continuously.

A leaning wall would be subjected to abnormal stresses of many kinds. In some buildings the brick walls do not bear any of the main loads, serving only for ornament and protection against the weather, while the weight of the building is carried by steel girders. Sometimes the outer walls of a house are made hollow. This results in there being really two walls, the hollow space between allowing for the insulation of sound and heat. To-day it is possible to incorporate a large number of sound-absorbing materials in walls for preventing the transmission of

noise. Asbestos is also used to render walls fireproof, and yet another consideration in big cities may be to make walls rat- or insect-proof. No machine has ever been invented for laying bricks, although it should not be difficult to devise one to apply the necessary mortar, lay the brick, and ensure that it was exactly square. Probably it would not pay us to use it, for an average bricklayer deals with about 800 bricks a day. In efforts to make a record, bricklayers have laid as many as 1,100 bricks in one hour.

Cement and concrete are two building materials which are becoming yearly more important. Many large buildings are constructed entirely of concrete and steel; even in the ordinary brick house cement and concrete are used for foundations, hearths, or similar details. A house must have foundations to spread the weight and to give stability. These supports are usually dug out and filled with concrete, while insulation from damp rising up the walls is secured by incorporating one or more layers of damp coursing in the lowest rows of brickwork. The damp course is either chemically treated concrete or some composite bitumen, felt, or slate. Below this course it is usual to find perforated bricks, so designed as to admit air to a hollow space under the flooring so that dry-rot may be prevented in the woodwork.

Cement is an artificial substance made by burning together chalky with clayey material and crushing the clinkers thus formed. When this powder is mixed with sand or larger stones in the presence of

water, a chemical action is set up which results in the mixture "setting" and hardening. Modern cements have the advantage that they set in a very short time and that it is possible to incorporate a large amount of sand or "aggregate," as the small stones are called, with a small amount of cement. As much as twelve parts of stones may be mixed with one part of cement to form a strong concrete; the technical difficulty is to ensure that all the surfaces of every stone are completely covered by the cement, so a smaller proportion of aggregate is commonly used. Concrete consists essentially of small stones bound together by cement, the proportions of cement, sand, or concrete varying widely with the job in hand and the particular conditions to be satisfied. A strong concrete can be made by mixing one part cement, three parts sand, and six parts aggregate. If, however, concrete has to stand under water, as in the case of harbour work, a much larger proportion of cement is mixed in order that the concrete shall be "close" and the magnesium salts dissolved in the water have no chance of entering to attack the lime. Curiously enough, cement is not affected by mineral oils, such as petrol, but is quickly influenced by vegetable oils.

The first step in making cement is to quarry the limestone, which is crushed with shale, slate, or other suitable rocks. The raw materials cover many varieties, but the essential is that one of them shall provide the lime. They are baked together in a large kiln and the resulting clinker ground exceed-

ingly fine. Very much depends upon the skill and accuracy of the chemists who at every stage take samples of the materials for blending. As exact composition of the materials can never be exactly the same, even when they are derived from the same sources, each blend has to be slightly different. To weigh out large quantities of the various constituents and mix them would be a laborious process, so that this mixing is carried out by automatic scales. The chemists, having analysed samples, give the proportions to be used and the automatic scales then govern the flow of each powder in these predetermined quantities.

The grinding mills are very interesting. After the larger pieces of stone have been crushed between massive steel jaws they pass to a grinding mill, which consists of a large revolving cylinder filled with heavy steel balls. As the cylinder revolves, these balls fall over and over, grinding the material between them to a fine dust. The grinding is important, because the composition of cement depends upon the combination of the lime with the silica and alumina, which cannot take place in the kiln unless the particles are brought intimately together. In another type of mill a heavy, flat steel roller is thrown against the outside of a steel cylinder by centrifugal force.

Two processes are used in making cement, the "wet" and the "dry." As the names imply, the difference is that in one case the raw materials are in water. By this method it is easier to obtain thorough mixing of the particles. In any event the ground

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[*Photo. Keystone-Underwood.*

MAKING "BRICKS" OF CONCRETE.

material is stored before passing to the bins, and it will be seen that in the wet process a further mixing continues naturally during storage: the liquid is kept continually stirred to prevent settling. Before the clinker actually formed in the kiln is passed to ball grinding machines, a little gypsum is added. This regulates the setting of the finished cement. The fine powder—it must be so fine that when it is passed through a mesh with 32,000 holes to the square inch only 10 per cent. remains behind—is packed in bags by automatic machines having valves at the bottom which open to let out a weighed quantity of cement into the bags as they pass underneath.

Why does cement set when mixed with water and allowed to dry? It is a very complicated matter, for a great number of chemical reactions take place. Intricate compounds are formed by a process of hydration, but chemists are not wholly agreed as to their exact nature. One interesting point is that concrete has many characteristics of a living substance, setting conditions continuing after many years.

This description applies to Portland cement, which is only one important example of many different kinds, although it has now almost entirely taken the place of the old lime cement. In many parts of houses Keene's cement is used. This consists of calcined gypsum. The difference between this cement and Plaster of Paris is slight, depending upon the temperature to which it is heated during manufacture. Plaster of Paris sets in a few minutes, whereas

Keene's cement sets in a few hours, and cannot be used where it is exposed to water.

Where stone is used to-day for building, it is usually hewn and shaped by machinery, which greatly reduces the labour involved; but very little stone is now employed for private houses. In large buildings it has the great advantage of giving bold effects and of being easily shaped. The commonest stone to be found in small houses is slate, which may be applied not only for roof covering, but for window sills, floors, doorsteps, and similar work. Slate is a very wonderful stone which was formed as the result of great rivers laying down silt which was afterwards subjected to enormous pressure during earth movements. This took place thousands, perhaps millions, of years ago, and in course of time the slate became covered with earth or other rock. It has therefore to be quarried and is found mixed with a good deal of waste stone. Indeed, it often takes six tons of rock to produce enough good slates to cover one small roof.

The slate is blasted and hewn out in slabs which may weigh up to four or five tons. These are sawn to shape and then split. Although slate is quite impervious to the weather, it can easily be split, along its laminæ, by a chisel. The largest slabs are used for the foundations of billiard tables and for monumental work. Other slabs are sawn down to the approximate size of a roofing slate, when they are handed to a splitter, who separates the sections with a few taps of his chisel. The slates are then trimmed by

a revolving knife. In this work, machines have not yet been devised which are as economical and good as hand labour. Large slabs of slate are cut with diamond saws and can be planed smooth like wood. It is a very curious stone, easily carved, but tremendously enduring, as tombstones more than three hundred years old can prove. The small slates for roofing are made to overlap so that the rain shall not leak, and are nailed into position on the roof.

The commonest slate is grey, but it is obtained in many different colours. The beautiful russet-red slate owes its colour to water containing iron salts which has seeped into the slate bed. The splitter expertly chooses the points of splitting so as to show as much colour as possible. Once in position, a slate roof seldom wears out, for the stone is unaffected by wet or frost. Some of the original slate roofs on Tudor houses are still to be seen.

Although hand labour is very important in slate quarries, science has provided means for easy transport of the stone to the surface and power for sawing and grinding. Originally, transport was by means of women or donkeys. Slate ground to a very fine powder is used in making cement, and as a " filler " for many things from brown paper to gramophone records. It is a most valuable material and one of the few substances that has held its own, from the days of old to modern times, where concrete is rapidly supplanting all other forms of construction.

CHAPTER II

CLOCKS AND TIME

In thousands of homes the strident ringing of an alarm clock announces the beginning of another day. Perhaps it would be asking too much of the listener to expect him, as he tumbles out of bed or turns over for just one more little nap, to offer thanks to the inventors whose patience and ingenuity gave us those clocks. If it cost more, time was less valued in the days before cheap alarm clocks, when a "knocker-up" was paid to walk down the street and tap on the windows. To-day you can buy an alarm clock for five shillings or less which will keep accurate time. It will call you for several thousand mornings, even if it is completely neglected and neither cleaned nor oiled. More expensive types can be obtained with an attachment to make a cup of tea automatically and to pull off the bedclothes after half an hour's grace.

We should be grateful to the alarm clock. Without it we must rely entirely on the "clock-in-our-head." This strange device of nature is reasonably accurate; many people wake up punctually at the same moment every day without any artificial aid, and others can wake themselves at a particular

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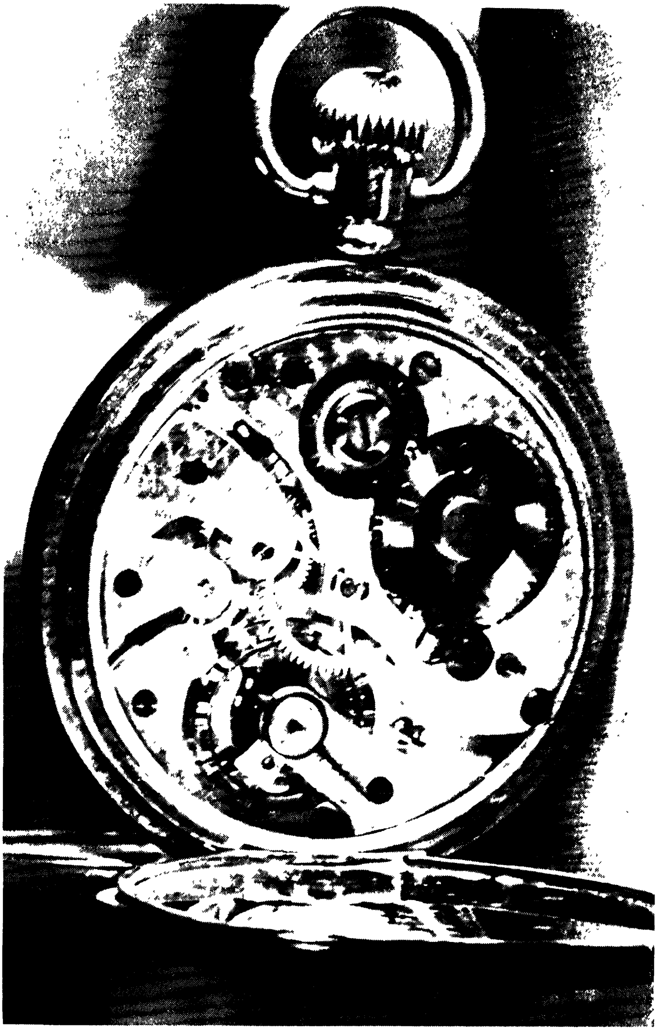


[*Photo: Keystone-Underwood.*

INTERIOR OF A WATCH.
(Magnified.)

time merely by making a resolution as they go to sleep. Science does not fully understand the working of this clock in our heads, although some very interesting experiments can be made by asking it to wake us up at particular hours.

But most of us are far too lazy to develop this clock, which at best is only approximately accurate. We have to rely upon the faithful alarm, and if too sleepy in the morning, we should, when we set it at night, remember all those inventors who have made it possible to manufacture this useful, efficient instrument for a few shillings.

The mass production of clocks, which brought them within the reach of the poorest person, originated in America. Formerly, the possession of a clock or a watch was a sign of wealth. A man named Eli Terry simplified clock manufacture when he began to substitute brass parts for wood. With his machine methods, he was able to sell clocks for about one pound each, as compared with the old price of nearly eight pounds for a hand-made clock.

The production of clocks in quantities was based upon complete interchangeability of parts. In hand-made types, a wheel in a certain clock may be very nearly like its counterpart in another, but it is not interchangeable. In mass production the assembly of parts is made easier and each piece can be stamped out quickly from sheet metal ; spare parts for repairs are also always available. Unless machine-made, it is doubtful whether alarm clocks could be made for less than a pound each under modern circumstances.

Some people imagine that "machine-made" and "mass-produced" are terms which imply poor workmanship. Every motor car made to-day proves that this is not true. Handwork in some cases may be superior, but the machines which make the parts of clocks are so finely adjusted that they are accurate to fractions of thousandths of an inch. They are made and tested by gauges to such fine limits that in the production of some automatic machines measurements of a millionth of an inch may be necessary. The tools that make the works of a five-shilling clock often cost many thousands of pounds.

The mechanism of the alarm clock is really very simple, and if an old clock is dismantled it is easy to see how it works. The alarm has two springs, one to work the clock mechanism and one to ring the bell. Normally the bell spring is prevented from unwinding by a small lever which is only released by a peg on the gear-wheel when the hands of the clock reach the position to which the alarm has been "set." Some alarm clocks, made for people who object to being awakened, have a second lever which is released a few minutes after the first. In this way the bell is rung a second time, to the disgust of the sleeper, who has turned over for just five minutes' more rest.

Our alarm clock in these days may be worked by electricity. The alarm mechanism works on exactly the same principle as that of a spring alarm, the bell striker being released at a given time by the clock mechanism. But the clock itself is based on an entirely different method.

The advantage of the electric clock is not limited to the fact that no winding is required. It can be made cheaply, and it is accurate. It is now possible to buy electric clocks at prices comparable with those paid for a spring clock of only moderate quality, and, in the future, we shall probably have electric clocks fitted to our homes just as much as a matter of course as electric lights or fires are supplied at present.

There are various types of electric clock, some of which are worked by small batteries which require renewing only at long intervals. In the battery clock there is usually some form of pendulum, so arranged that as the weight swings a contact is made which allows an electric current to flow round the coils of a magnet. This magnet attracts the pendulum, which, after half its travel, breaks the contact and allows the pendulum to swing until it is again in the position to be attracted. The process is not unlike that of an electric bell in which the clapper is replaced by a weighted pendulum. The most popular clock, however, is that which is "mains operated." It consists of a small synchronous electric motor, and not very much else; depending for its timekeeping qualities upon the fact that alternating current is now produced with a standard frequency over large areas. In stations taking power from the Grid scheme, the frequencies vary only by a few cycles a day, and the clocks therefore run with a gain or loss represented by a fraction of a second in twelve hours.

Every time the current alternates it rises to its maximum, dies away to nothing, and grows again

to its maximum in the opposite direction. If this current is converted to the wires of an electro-magnet the magnet is energized at each pulse of the mains current. Every time the iron of the magnet or armature becomes magnetic it pulls round one tooth of a cogged wheel in which the cogs act as a series of magnet " keepers " not quite touching the poles. The wheel therefore is rotated in time with the current pulsations, and as these are kept at exactly the same number in every second, the motor can be used to drive the hands of a clock. The motor runs very slowly and is therefore quite silent. We shall have to eliminate the ticking of the clock at the fireside as one of the pleasant sounds of life in the future.

Your alarm clock, perhaps, wakes you at seven o'clock, but have you ever paused to think what we mean by seven o'clock ? " Of course," you say, " it is when the little hand of the clock points to seven and the large hand to twelve " ; but that hardly answers the question. Your clock may tell the " right time," but it does not tell the same time as a clock in New York. Which is right ? And why should not the hour at which you get up be known as two o'clock or nine o'clock ?

Time is a technical, and sometimes a controversial, subject. Occasionally it is called a dimension —like length, breadth, and thickness. When we talk of time we mean, generally, the time registered by a clock, but the scientist uses a capital letter and speaks of Time in another sense. It is surprising how even

knowledgeable people are often confused about time and wonder whether the clock ought to be put forward or backward for daylight saving, or are puzzled about what happens to the half a day which you " gain " by the clock when travelling to Australia.

The first men measured their time by the rotation of the sun in the sky. For they thought it was the rotation of the sun, when, in fact, it was rotation of the earth. After thousands of years we still use the rotation of the earth as the basis of our time measurement. Other apparent constants of time have been found, but the rotation of the earth remains sufficiently accurate for our purposes. We do not, however, use solar time, but sidereal time; that is to say, we note the " passage " of a certain fixed star at a certain hour and note its passing across the same telescope again the next day. The intermediate periods are then divided into twenty-four hours, each of sixty minutes of sixty seconds. These divisions are merely for convenience, like the inch divisions on a yard ruler. Just as the yard is the standard length, so the day is the standard time. It would not alter our time at all if we decided to introduce a metric day of a hundred hours, each of a hundred minutes. It would merely call for the rearrangement of a few cogs in our clocks and an alteration of dials.

Mechanical clocks mark off this time, and the very finest of them are sufficiently inaccurate to render some check necessary. If we did not check clock-time by rotation of the earth we should find, in a hundred years, that not only did all the clocks

in the world disagree, but that some made it 2 p.m. at sunset while others showed the sun as setting at six o'clock in the morning.

Time is checked at various places. In Great Britain we depend upon the Greenwich Observatory, where every day observations are made and the "passage" of a star over the crossed spider's webs of a telescope is noted. Greenwich gives its "pips" to the world and that is the " right time."

Time throughout the world is so many minutes and hours " fast or slow " of Greenwich. To ships, time is particularly important, because it is used in calculating their position. All ships carry very accurate chronometers, although in these days wireless enables them to make corrections without difficulty. Time is the same all over the world, but for the sake of convenience we put the clock on going east, and back going westward. Thus a ship travelling at exactly the same speed in both directions appears to take about eleven hours less going to New York from Southampton than it does coming from New York to Southampton. In one case the clock has been put forward, and in the other, back.

At the part of the world twelve hours slow of Greenwich if you have been travelling west, or twelve hours fast if you have been travelling east, is an imaginary line called the International Date line, and whenever a ship crosses this, it has to go back a day or skip a day according to the direction in which it is travelling. The line is not straight like the Greenwich meridian, but zigzags to avoid land, so

that no one shall live where convenient time does not exist on the " map."

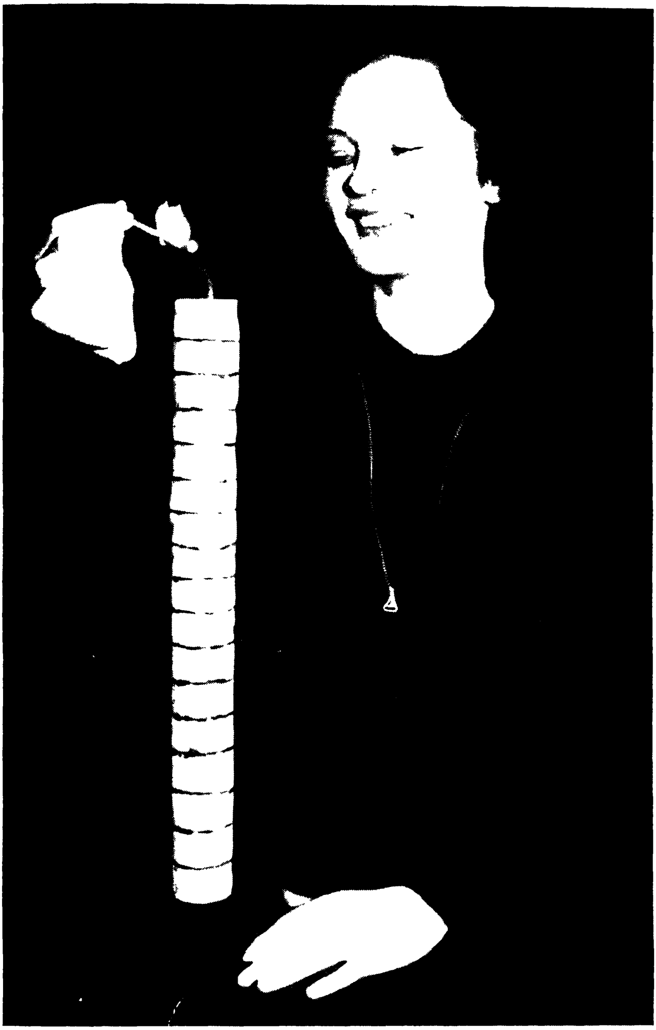
All this may seem very remote from that alarm clock that woke you up, but it is quite important. Suppose, for instance, that a friend, learning that you can telephone cheaply to New York, asked you to ring him at 2 p.m. on the next day, as he was sure to be at home. At 2 p.m. by your clock you ring him up, to find that he has not yet come in, and feel annoyed. But you should have remembered that when he said 2 p.m. he meant 2 p.m. by his own clock, and when your perfectly accurate clock showed 2 p.m. his would show only about 9 a.m. You ought, therefore, to have waited until seven before telephoning.

When "Daylight Saving" or "Summer Time" was first introduced there were many ignorant people who attacked it on the grounds that it was " interfering with nature." Even if we assume that these people weed their gardens, which is equally interfering with nature, they were on the wrong track. Nature's time remained exactly the same. All we do when we introduce Daylight Saving is to trick ourselves. There would be no need to put the clock on an hour in April if every one would agree to get up an hour earlier, go to work an hour earlier, come home an hour earlier, and go to bed an hour earlier. This is what we do, in effect, but to save complications we solve the problem by putting the clock on an hour. This makes it appear as if the sun is setting an hour later ; but even the ingenuity of

William Willet, who " invented " Daylight Savin and King Canute combined could not make t sun set later by this one hour.

Some parts of Gt. Britain have partial Daylig Saving all the year round ! If you live at Lan(End, for instance, the sun sets an appreciable tii later than in London. Of course, it also rises lat and for the sake of convenience the whole of t British Isles keeps to one time, although this is oı theoretically accurate on a thin line drawn north a south through Greenwich. The days do vary length in different parts of Gt. Britain, but this i question of longitude, whereas time is a matter latitude. In a big country like America they h: to have four different times, otherwise they wo find that sunset in San Francisco was at 1 p.m. wl it was at 5 p.m. in New York ! People would ne have opposed Summer Time on the grounds tha was "against nature" if they had understood meaning of time as used by the world.

In the early days of man, people kept tl appointments according to the sun or the mc They met " when the sun is high," or made appointment " at the rising of the moon." It very casual, and no doubt cavemen were often hour or two late for an appointment, simply bec: the expressions used were so vague. The neces for a greater number of divisions in the day bec obvious in the first sundial " clocks." No doubt stump of a tree or a prominent rock was used to a shadow. There were obvious inaccuracies in



[*Photo Keystone-Underwood.*

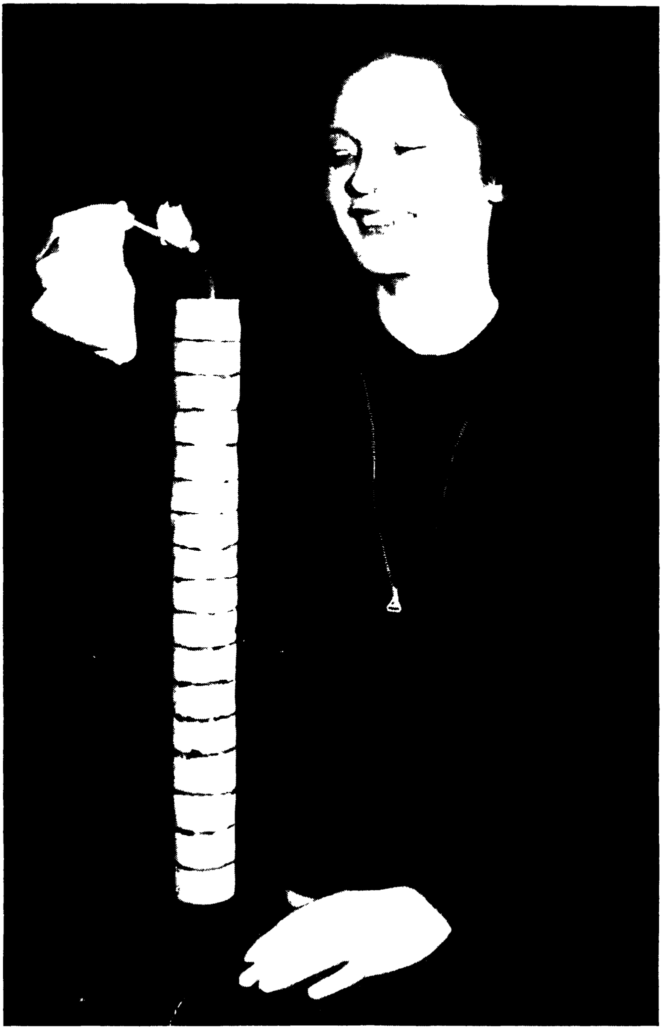
LIGHTING AN OLD TIMEKEEPER.

(A candle marked in sections, each of which takes fifteen minutes to burn away.)

William Willet, who " invented " Daylight Saving, and King Canute combined could not make the sun set later by this one hour.

Some parts of Gt. Britain have partial Daylight Saving all the year round! If you live at Land's End, for instance, the sun sets an appreciable time later than in London. Of course, it also rises later, and for the sake of convenience the whole of the British Isles keeps to one time, although this is only theoretically accurate on a thin line drawn north and south through Greenwich. The days do vary in length in different parts of Gt. Britain, but this is a question of longitude, whereas time is a matter of latitude. In a big country like America they have to have four different times, otherwise they would find that sunset in San Francisco was at 1 p.m. when it was at 5 p.m. in New York! People would never have opposed Summer Time on the grounds that it was "against nature" if they had understood the meaning of time as used by the world.

In the early days of man, people kept their appointments according to the sun or the moon. They met " when the sun is high," or made an appointment " at the rising of the moon." It was very casual, and no doubt cavemen were often an hour or two late for an appointment, simply because the expressions used were so vague. The necessity for a greater number of divisions in the day became obvious in the first sundial " clocks." No doubt the stump of a tree or a prominent rock was used to cast a shadow. There were obvious inaccuracies in this



[*Photo Keystone-Underwood.*

LIGHTING AN OLD TIMEKEEPER.

(A candle marked in sections, each of which takes fifteen minutes to burn away.)

method, for the sun rises in a different place every day, and a sundial is slow or fast on all days of the year except four. In addition, the sundial is useless at night and on very cloudy days.

Other methods of recording the time came to be invented. A candle was marked off in equal bands, each of which burned away in an hour. This was reasonably accurate, although unevenness in the wax would make it very unreliable by modern methods of timekeeping. The great disadvantage was clumsiness. A candle could not be left to burn in the pocket or put up in a public place. The same troubles applied to the water clock, in which the passage of time was noted by measuring the water that had passed through a small hole in a glass vessel. Moreover, the water ran rather faster when the vessel was full than when it was nearly empty. Sand clocks were another idea, and the probability is that there is one in most houses. Although sand-glasses would hardly serve as timekeepers to-day, they are still excellent for measuring the three or four minutes required to boil an egg. At three or four minutes a sand-glass is still reasonably accurate, but for longer periods the nuisance of having to turn it over would be intolerable. An hour-glass was often used by speakers to time a sermon.

Although one of the makers of a water clock actually fitted a pointer with cogs to tell the time, it was not until many years later that watches and clocks were developed. The first clocks depended simply upon the division of time into sections by

means of cogs, usually driven by heavy weights which fell slowly. The real birth of clock- or watch-making dates from the invention of the pendulum, or rather from the study of its properties, and until the invention of the electric clock all good clocks depended upon this principle. Galileo first noticed that a pendulum of given length always took the same time to swing, however far it might swing. The weight might move only two inches or a yard, but it took exactly the same time. He also found that the time taken was directly dependent upon the length of the pendulum.

Galileo never made a pendulum clock, although he did suggest to doctors that the pendulum afforded an accurate method of taking a patient's pulse. Others adapted it to clock-making, and it is the pendulum that " keeps time " in a clock. The most accurate clock in the world, more accurate than an electric clock, depends upon a pendulum. The mechanism of the Shortt clock, as it is called after its inventor, is kept in a separate case from the pendulum, which is as nearly " free " as man can make it. It keeps perfect time to a fraction of a second a year ; quite apart from its delicacy, we are not likely to see it introduced into our homes, because it is so easy to correct an ordinary clock once a week or as often as may be necessary.

In a small clock and in watches a balance wheel takes the place of a pendulum. The spring gives a " kick " to the balance wheel in the same way as the spring or weight in a clock gives a kick to the pendu-

lum. The pendulum is attracted to its resting position by the earth's attraction and the balance wheel by its spring uncoiling until the energy of the spring is dissipated. At the South Kensington Science Museum, London, is a tremendously long pendulum, which is released so that it swings along a certain line. As the minutes pass, the "plumb" deviates from its original path, due to the motion of the earth.

Thus we have passed from keeping our appointments to the nearest hour to measuring the running of a hundred yards race in tenths of a second, and from the clumsy old clocks which used to weigh many hundredweights to a lady's wrist-watch weighing a few ounces, with jewels for every pivot. Those jewels are not put in, as many people imagine, to make the watch expensive, for if that were the case they would undoubtedly be placed on the outside. They are fitted to the bearings because, being exceedingly hard, they are never likely to wear out. Not, that is to say, in all the time that need ever be maintained.

CHAPTER III

WASHING AND SHAVING

Although washing is as much a daily task as getting up in the morning, very few people know what happens when soap is lathered on the face or scrubbed into the hands with a nail brush. They know that dirt comes off into the water, but the reason may seem quite unimportant. Scientists were puzzled for many years as to the actual effect of soap, although its uses are mentioned in the Bible and were known to the ancient Phœnicians.

Before we can understand how soap works we must know what it is. There are many different kinds, but, chemically, they are all closely allied. Consistency, colour, or perfume may vary, but these are usually details controlled by the soap manufacturer to please the eye and nose. Soap is a substance formed when a " fatty acid " combines with an alkaline base; it is a definite chemical with a definite, and rather long, chemical formula. There are several fatty acids, amongst which are stearic and oleic. The alkaline bases used for soap are mostly sodium, potassium, or ammonia compounds.

The cleansing action of soap is now believed to be as much physical as chemical, and its secret is to

be found in the soap bubble. Every one has blown soap bubbles, but it is not always observed how tremendously strong that very thin film of soap and water must be to withstand the pressure inside. The film is only a few molecules thick, and, in the case of minute bubbles, pressures of many pounds per square inch are common.

The explanation is that soap with water forms a liquid with a very high surface tension. This means that when the soap comes into contact with dirt and grease it works its way beneath the layers. The dirt is emulsified and the free alkali, present in only minute quantities, is able to continue its chemical work. As soap is made by the action of a fatty acid on an alkali, the release of this alkali from the soap in water produces more soap by mixing with the grease of the dirt. Most of those greases contain fatty acids, for there are many kinds of dirt in addition to the sebum which the skin throws out.

The emulsifying or lubricating effect of soap is shown by the fact that when lamp-black in water is filtered through a piece of paper, the lamp-black is left behind. When the lamp-black is mixed with soapy water, the soap carries the black through the paper. It is supposed that compounds are formed which have little power of adhering to polished surfaces such as our skin, which is naturally greasy. A good soap will set free just enough alkali to dissolve the grease and allow the dirt to be lifted away by the action of a lather. Some of the skin oils must be allowed to remain, or even replaced, so that the skin

shall not become dry, unhealthy, and liable to permit germs to enter its pores.

That the action of soap depends so much upon surface tension has provided a way of testing the qualities of different soaps. It is not easy to determine the washing ability of a soap by chemical analysis, although such tests may show the presence of certain desirable chemicals or the absence of those which are not required. This, of course, does not give the surface tension of the soap solution, which may be discovered by dropping a very small quantity of soap solution from a fine tube on to the surface of an oil. The solution forms a number of little globules, and the number depends upon the value of its tension. By comparing the number of globules with the number produced by standard solutions a scientific estimate of the value of the soap can be made. Soap is also tested by running water of a given temperature over a piece of standard dimensions and measuring the amount that dissolves ; if soap contains a great deal of insoluble matter or material that only dissolves with difficulty, it is obviously of no great value.

Another test applied to soap is to make a jelly by dissolving it in hot water and allowing this to cool. A glass tube is then placed upright on the surface of the jelly and small weights are gradually added until the tube breaks the jelly. It is the physical as well as chemical properties of soap that are of such importance, for it is one of the main domestic preventatives against disease, and its pre-

paration should be safeguarded by every check known to science. Proper cleansing can prevent unpleasant odours and assist the skin in its breathing action.

Soap is manufactured in a number of different ways from a very wide variety of substances. Any natural container of fatty acids will make soap, and the range of such materials is steadily growing. Many animal fats are used, such as tallow, lard, bone fat, and grease. Then there are the vegetable oils—coconut oil, palm oil, olive oil, cottonseed oil, and others. More recently, resin has been used. This is a substance obtained as a by-product when turpentine is made from the gums exuded from certain trees. The choice of the raw material depends very much upon the quality, price, and purpose of the finished soap. It cannot be said that one substance is definitely better than another. Some good materials are rarely used because of the high cost, but on the other hand the use of resin, which is often taken to indicate a cheap soap, may be definitely beneficial in certain types as a preservative. It helps soap to "keep." In most soaps there is a mixture of several different kinds of fatty acid.

Various alkalies and oxygenating agents are used in linen washing soaps, while potassium alkalies are used chiefly for "soft" and shaving soaps. Many perfumes are also employed. Sometimes it is an "essential oil," prepared from natural sources, such as almond or lavender; sometimes it is a synthetic perfume which gives an odour very similar to that of

a natural substance although completely differing from it in chemical structure. Other good soaps are what is called " medicated " and contain coal tar, carbolic, or some other disinfectant. This disinfectant, which is present only in very small quantities so as not to harm delicate tissues, is brought into very close contact with the skin and can therefore prove of considerable service. After an infectious illness, a bath with medicated soap is usually advised, but even in everyday life it is good to use a disinfecting soap for washing hands or floors. If the hands could sometimes be seen through a microscope, when apparently clean, it would be only too apparent that there is ample scope for the destruction of bacteria.

In the soap factory, alkali, generally in the form of soda ash, is added to the " stock " of fatty acids in huge boilers which are heated by steam jackets or pipes. In one special process the soap is made to heat itself. Caustic soda is used, and it is not necessary to heat the mixture, except at first, because the chemical reaction makes its own heat. This method cannot always be employed, as it requires certain types of fat and often the addition of coconut oil.

Soap-making is a very technical process, even though the chemical reactions involved may seem simple. The exact practice varies considerably with different raw materials. Above all, great care is necessary, so that there may be no excess of free caustic alkali to burn the skin, although a little more alkali is permissible in soaps intended for scrubbing.

Photo: Keystone-Underwood.

BOILING SOAP.

At one time it was not uncommon to find a batch of soap which produced an unpleasant burning sensation on the skin, but nowadays constant laboratory tests are made of the products at every stage and it is practically impossible for serious mistakes to occur.

Soaps dissolved in water can be " thrown out " by the addition of salt; this is obvious when ordinary soap is used with sea-water, for soap will not dissolve in a strong solution of salt. In manufacturing of soap this is additionally important, because it enables glycerine—which is also produced during the action of an alkali on a fat, and is soluble in salt water—to be recovered. Glycerine is now a chemical of great importance and is used for innumerable purposes. Under the influence of salt the soap separates out in a granular mass and floats to the top, while the glycerine remains dissolved in the salt water, which is afterwards run off. The soap itself is subjected to further treatment for purification and eventually run into large frames to become hard. It is then cut into bars, milled, stamped, and probably dried for a further period before being packed for the market. Toilet soaps often undergo further processes, which include squeezing out the air or adding the colouring and perfuming matter. Moulding and packing is usually carried out entirely by machinery.

In connection with soap-making there is one process which is important because it bears upon so many other industries. For a long time manufac-

turers had available raw material that closely resembled the fats required for soap-making, but contained two atoms less of hydrogen. This substance was almost useless until some years ago the ingenious process of " hydrogenation " was invented. It is carried out in various ways by using a catalyst, a substance that promotes chemical change without taking part in it, such as nickel or palladium, and by high pressures. These " hydrogenated " oils are now widely used, and the process is becoming of great value, for by adding missing hydrogen atoms a quite inedible fat can be turned into good food, or an oil that is poor for purposes of lubrication can be converted to exactly the form required for various classes of machinery. New fuels are also being prepared by an adaptation of this principle.

Closely allied to washing is shaving; but in shaving the soap is required for quite a different purpose. Shaving soap is essentially the same as washing soap, except that it is designed to have lathering rather than cleansing properties. The shaving soap we squeeze out of tubes is much the same as others, except that more water and perhaps alcohol or some other chemical has been added to keep it moist.

There have been arguments as to why a lather makes the many small hairs on a man's face soft. It has been stated that, in fact, soap has very little action at all, and that it is the hot water which counts. Certainly even a good lather with cold water is not so effective as a moderate lather with hot water. In

all probability the main action of the soap is as a lubricant, and this is borne out by the wide use of shaving creams which form no lather, but are merely rubbed on to the skin. Here again it is the surface tension of the soap solution that matters. It forms a large number of strong small bubbles that hold the hairs upright when the razor reaches them, and makes them easier to cut; just as it is easier to cut a field of wheat that is standing up straight than to cut a field which has been badly beaten down by rain.

In making a shaving soap the manufacturer also aims to produce a material that will give a lasting lather. When some ordinary soaps are used for shaving a good lather may result, but it will disappear before there is time to shave. These are generally potash soaps, so that soda is always used for shaving soap in order that the lather may hold. Various oils can be added to shaving soap to improve its lubricating qualities, and the use of disinfectants is also quite common, although it is difficult to obtain any really powerful bactericidal effect with so much dilution.

The razor is, perhaps, even more important than the soap. We always speak of a razor blade as being very sharp, and if the blade is closely inspected it seems to be a thin fine line. But under a powerful microscope it shows a saw-like edge. A razor becomes blunt when the edge is even more jagged, and this is brought about by minute particles of steel being rubbed away. The greatest enemy of a razor is rust, which, even if it is not visible, will blunt

a blade very quickly. For this reason razors should be wiped very carefully and sometimes given a coat of grease to keep out the air altogether.

Some men talk of a blade lasting a " week or a month," and would probably be surprised to learn that it really lasts less than one minute. Fifty seconds is calculated to be the " active life " of the average razor blade ; that is the time it actually spends in cutting hairs. The rest of the time it is not in contact with the hair at all. In the course of a shave a razor may cut 25,000 hairs, and this it does in five seconds of cutting. Some ingenious person has timed a razor in use and found that it moves at between twenty and thirty feet a second, or about 25 m.p.h.

The safety razor is now almost universal because of its convenience, but our fathers nearly always used "cut-throats." Some of them kept seven razors in a special box, using one on each day of the week in rotation. They said that in this way they had a better shave, and it was not altogether imagination. We now know that the molecules in steel rearrange themselves, and although these changes are far too small to observe, even with the most powerful microscope, it is a fact that steel things, like human beings, may occasionally improve by resting. This applies to aeroplane engines as well as to razors. Steel can become tired. It is technically called " fatigue " and is responsible for some accidents which could not be foreseen when even microscopic or ordinary X-ray examination did not show what

was happening. Razors are also sensitive to the cold. Most men dip their razors in hot water before they begin to shave, but science suggests that they should warm them even before stropping, as this makes the molecules more active and therefore easier to " push into line."

There is a common belief that razors are sharper if they are kept pointing towards the north. This is based upon the idea that they are magnetized. It is more likely to be the result of psychological effect, as in the case of people who claim to sleep better when their bed points north or south. Washing and shaving processes have not vastly improved over the centuries. Mechanical or chemical devices are likely to be seen in increasing numbers now that labour-saving has become a worth-while study of the future.

CHAPTER IV

LIGHTING THE FIRE—COAL AND GAS

One of the first tasks in the morning is to light the fire which will heat the house, cook the breakfast, and probably warm the water for a bath. Gas and electricity are coming more and more into use, but the coal fire still remains a firm favourite. We are slowly learning to burn coal and coke more efficiently, and, as a matter of fact, tests have shown that our grates and boilers are not so inefficient as might be thought. In many districts where the cost of electricity and gas is high, coal is the cheapest means of heating. It is not always the most convenient method, for a coal fire takes time to light, longer to reach its maximum heat, and requires regular attention, while gas, oil, or electricity can be used equally easily for a few minutes or a few hours.

The deciding factor with many people is the pleasant glow and the flickering flames of the coal or wood. The love of a coal fire is typically English. In many other countries they burn their coal or other fuels in closed stoves. For the sake of these dancing flames and a few useful rays we are prepared to put up with the dust which is inevitable in the room, the dirty business of cleaning chimneys, or the

still dirtier business of finding our way through " pea soup " fogs, which are largely due to our habit of burning coal in open grates.

When warming our hands at a coal fire we are feeling the heat of the sun given out millions of years ago. The heat has been chemically stored in the coal all through the years, and we release it by heating it until it can eventually heat itself. The coal was formed by thick vegetation growing in humid jungles and sinking into the ground. Layer after layer of vegetable matter, which owed its growth largely to the absorption of the sun's energy, was laid down. At some time, perhaps thousands of years later, one of the terrific earthquakes that were a daily occurrence in those distant times twisted the ground. The layers of decayed vegetable matter were folded over, buried under terrific pressure, and a " seam " of coal was formed. It took nature thousands of years and forces many times greater than we can produce to-day to make coal. We have never, in fact, succeeded in making synthetic coal. Oil, produced in a similar manner, owes its existence to both vegetation and creatures from old sea beds.

Britain was one of the fortunate places chosen by nature for the " manufacture " of coal. Nature did all the work, leaving the coal buried, so that men had nothing more to do than the mining. Perhaps if we had had some share in the making of coal we should be more careful how we used it, instead of losing half the more valuable by-products up the chimney or into the dustbin, and remaining content with a

bare 30 per cent. of the heat in our rooms. We consume in our homes about forty million tons of coal each year, but we could obtain just as much heat from one-third of this amount if we burned it more efficiently, so that all its heat was used for warming rooms or heating water.

Yet this forty million tons is only a fraction of the total amount of coal mined. Many millions of tons are needed for producing power—power to drive locomotives, power to drive the dynamos that supply us with electric light, and power for factories. More coal is needed for the manufacture of gas and in the making of steel from iron ore. In all these processes, except that of steel, we are "cashing in" on the sun as it shone millions of years ago. It is curious to note how much trouble we have to take to store energy for a few hours, as in an accumulator or a boiler, and how easily and efficiently nature has stored it for countless centuries.

There are various kinds of coal, and each has its special uses. A coal merchant may give fancy names to his various coals, but in many cases these do not mean very much. One day we shall probably insist upon our coal being sold, not by the ton, but by the therm, as gas is sold, for what is important is not to receive a ton of black lumps but to buy a certain amount of heat. In most houses the only varieties of solid fuel used—apart from what is called "ordinary coal," whether it be kitchen nuts or Derby brights—are anthracite, semi-coke, and coke. Anthracite is a very hard and old coal having many advantages; it

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[*Photo: Keystone-Underwood*

A COAL MINER AT WORK.

smokes very little, glows intensely, and contains a high percentage of carbon. The disadvantages, for certain purposes, are that it must be burned in a closed stove with a strong draught, that it is much more difficult to ignite than ordinary coal, and that it has to be broken very small. It is also more expensive from the point of view of weight, but, penny for penny, more heat is obtained from an anthracite than from ordinary soft "bituminous" coal. It is now widely used in kitchen boilers, for it can be left safely burning for twelve hours or more.

Various grades of bituminous coal are used in the house, and other kinds are used for raising steam, making coke, and similar work. Semi-coke and coke are being used more and more. When coal is heated in a closed vessel, known as a retort, various products are given off. Coal gas is one of them, but there are also volatile oils, tar, and many other chemicals. The hard black substance left is coke. A great deal depends upon the temperature at which the coal is distilled. At one time coal was always heated at a high temperature, but more recently low temperature processes have been introduced. The residue in this case is semi-coke, a substance which burns much more freely than coke, but, like coke, does not emit any smoke. This semi-coke is now a popular fuel under various trade names, and although it is more expensive, because it contains many valuable compounds that are missing from ordinary coke, it can be burned in an open grate, whereas coke usually requires a special grate or a closed stove.

The coal delivered at your door in sacks is not, of course, very much like the coal as it comes up from the pit. Before it is sent out for domestic consumption, coal has to be broken and graded, and all the best coals are freely cleaned. The breaking and grading or screening is carried out by machinery. Pieces of stone are picked out, the dust removed, and in many cases formed into balls or bricks under pressure. Anthracite, which has to be broken small and is very hard, is crushed between rollers.

We often talk about seeing pictures in the flames of a fire as we sit over it in a darkened room, but whatever stories our imagination may create, they could never be more wonderful than the truth of what happens in every fire. When coal is heated in the presence of air the gases are ignited, together with the tar and volatile oils. The ash which falls to the bottom of the fire and the products that escape up the chimney contains many valuable chemicals which, in proper plants, are turned into a thousand things—varying from aspirin to fertilizer. When, in fact, nature submerged those forests millions of years ago, she preserved not only the heat of the sun, but a wonderful store of raw materials. We meet things made directly or indirectly out of coal during every moment of the day.

Let us see what happens when coal is heated in closed retorts. In this way we shall not only understand something of what happens in a fire, but also trace how the coal gas which is used for cooking reaches the house. We call the places where coal is

treated " gas works," but to-day, although it is true that gas is still one of the main products, we obtain a very great deal more than gas from our coal. Many of these gas works are of tremendous size. One of them, which supplies only a part of London, produces about 120 million cubic feet of gas each day.

In a modern gas works most of the work is carried out by machinery. The coal is carried from the unloading quays to the retorts by conveyer-belts four or five feet wide, and after crushing, may be fed into the retorts by a projector. The retort door is thrown open and a charge of fine coal is blown like a shot from a gun into the interior. The door is then closed and the projector passes on to the next retort. Usually the retorts are in banks ; there may be three or four hundred of them in a single gas works. The retorts are D-shaped and made of silicious material which resists very high temperatures. When all the gas and other products have been driven off, the coke that is left is pushed out of the retort, cooled, and carried off, perhaps to be used in the " producer plant."

Coal gas is not the only gas made to-day by a gas works. In the days when we depended upon a " bat's wing " gas jet to provide light, the lighting quality of coal gas was important. To-day this is not so important, for although we may use gas for lighting our houses, our lamps are fitted with mantles and these only require heat. Therefore gas to-day is measured in therms, that is, in heating ability, and for

the sake of economy the pure coal gas is mixed with carburetted water gas.

When steam is passed over red hot coke, a chemical action takes place and carbon monoxide is produced among other substances. This "producer gas" burns with a hot flame, and after having the moisture removed from it, is purified like coal gas. The gas may be "carburetted" with oil to improve it, and in one large gas works 70,000 gallons of oil are used every twenty-four hours.

As the gas comes from the various ovens it is very impure, and most of the gas works is devoted to its purification. If it was supplied in the same form in which it comes from the ovens it would make a terrible smell when burned and probably choke the burners in a short time. Quite apart from other considerations, the gas company is only too glad to remove the impurities, for although these may be a nuisance in coal gas, they are very valuable for other purposes. The gas is first cooled, and the water vapour condenses. It is then washed to remove tar and ammonia. These are two valuable by-products. We use many thousands of gallons of tar on our roads, and ammonia is the basis for the manufacture of a number of chemicals, including a very valuable fertilizer.

From the ammonia washers, the gas passes to an apparatus which removes the hydrogen sulphide, an evil-smelling gas which you probably know well from bad eggs. It is most important that this impurity should be extracted. The blackening of some

white paints in rooms where open fires are burned is often due to the emission of hydrogen sulphide. Naphthalene is also removed by washing with gas oil, and this, together with some of the liquid hydrocarbons, may be returned to the carburetted water-gas plant.

Coal contains a certain amount of oil. It is not exactly like the natural petrol which we mostly use in our motor cars, but some of it makes a very efficient motor fuel, and the gas may, therefore, be "stripped" of its benzol. This, of course, is only worth doing when the gas is being made in huge quantities. In the case of a large gas works, about 16,000 gallons of benzol a day may be produced. The oil is collected by the use of special carbon, which absorbs the hydrocarbon vapours but allows the gases to go free. This gas is introduced into a vessel packed with activated carbon; the oil in the form of vapour is absorbed, and the gas is then turned off and steam introduced in a coil passing through the vessel. The oil is distilled and collected by being cooled. The gas, meanwhile, has been passing through a twin absorber, and as soon as the first container has had its oil removed it is passed back, the second container then being heated by steam. The cycle continues indefinitely, the activated carbon only requiring renewing at long intervals. Fuel oil is also made from coal by hydrogenation. In this process oil is mixed with the coal in the presence of hydrogen, the main constituent of coal gas, under high temperature and pressure. The pressure of

a catalyst permits extra hydrogen to be absorbed to form a new hydrocarbon oil. If means existed for easy transportation of gas this process might become of extreme importance on account of the possible economies involved.

Coke is produced in special ovens, which are very much larger than the retorts used for gas. A single oven will take a charge of sixteen tons, and there may be sixty of them arranged in a battery. The exact time of heating depends upon the type of coal being used and the type of coke required.

In a first-class gas works nothing is wasted. Hot gases passing from the ovens, for example, may be used for heating in some other part of the plant. Surplus steam produced in one process is used for driving an engine in another. More particularly is this the case with the chemical recovery when almost all the "waste" produces something useful. It is the gas that is really the by-product of a gas works.

When the coal tar is distilled, the first products to be given off are light oils. Later come heavy oils, and there is left pitch, a mixture of some two hundred different substances, including phenol—or, as we call it, carbolic acid—benzene, toluene, and anthracene. From these materials an astounding list of chemicals is prepared. To them we owe many of our most beautiful synthetic dyes, although it is a complete myth that it was the beautiful colours produced by tar in water that drew Perkins to think of the possibilities of dye manufacture. It is not the dyes that produce the colours, but the refraction of the light

by the very thin film of oil on the surface of the water. A vast range of synthetic drugs is also made from the coal tar, as well as scents and essential oils. High explosives are another important group of chemicals derived from coal tar, the best known of them being, perhaps, tri-nitro-toluene, popularly called T.N.T. Paints, varnishes, saccharine—which is many hundred times as sweet as sugar—creosote, inks, and aspirin are just a few things, chosen at random, which are built up from coal tar products. From phenol and formaldehyde alone a tremendous number of substances are manufactured, and without them we should not have the wide range of plastic articles which are now of such importance in building or the home.

During all these processes our house gas is being " boosted " or given sufficient pressure to pass along miles of pipes, through thousands of meters, to heat or light our homes. One of the few disadvantages of gas as an illuminant is that the heat carries up particles of dust and marks the ceilings. This is in no way due to the impurity of the gas, but is simply a question of heat. Now that we have efficient mantles, gas produces a light as effective in its way as that of electricity. We owe the mantle to several chemists, but notably to Baron Auer van Welsbach, who found that when cotton fabrics were soaked with the oxides of certain rare metals, such as thorium, a brilliant light was emitted at high temperatures.

Before this time, we had used gas purely as an illuminant, that is to say, we depended upon the

natural luminosity of the flame, as with a candle. Welsbach invented the mantle in about 1885, and brought also a new era of gas lighting. More recently it has been found possible to use mantles with oil flames, and thus a far more brilliant light is available in those homes which are still beyond the reach of gas or electricity.

There are many people who believe that the burning of coal in open grates should be forbidden, so that there would be less smoke in the air. Factories are often blamed for the fogs of our large cities, but a few hundred thousand ordinary house chimneys produce far more smoke than all the factories put together. Smoke is a sign of waste, and in industry such loss would soon be stopped. Neither is it altogether true that smoke is responsible for our great city fogs, for they are largely produced by air conditions. A fog consists of small particles of water vapour, but an ordinary fog can be made very much worse by suspended particles of soot. Without smoke we should not, at least, suffer from "pea soupers," quite apart from the fact that the soot represents a great deal of lost money. It is estimated that the loss of time and the damage done to buildings by fog costs us many millions a year. Much of this damage is due to sulphuric acid, which is formed in the atmosphere from the waste products of our chimneys. Sulphuric acid is a valuable chemical in the right place, and the work of the modern industrial chemist lies in producing things where they are wanted.

Although much has been accomplished with coal,

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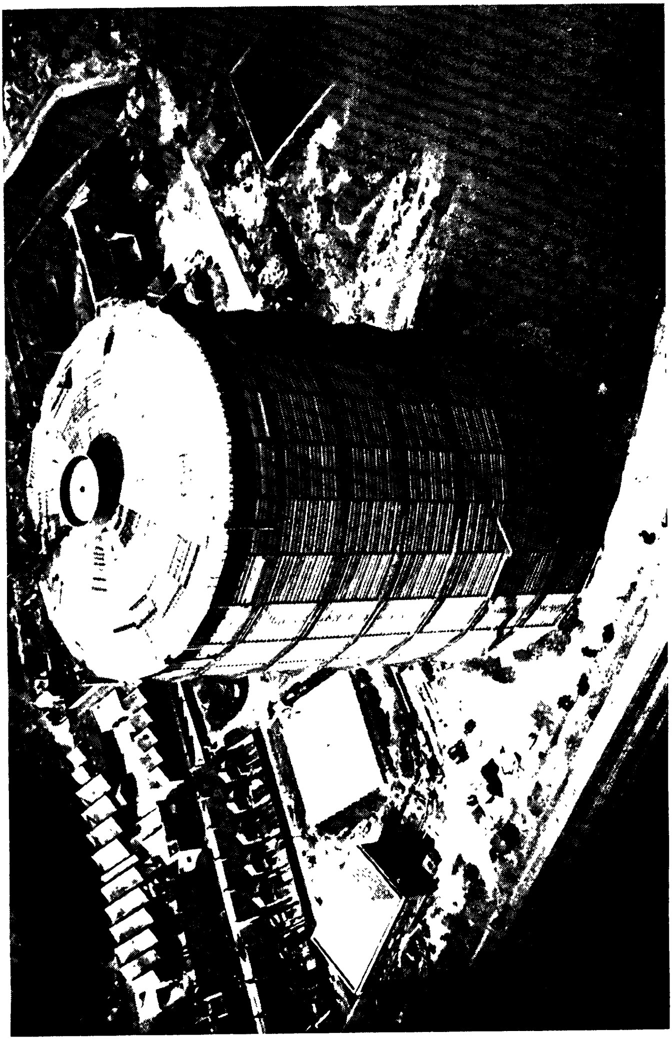

[*Fox Photo.*

GASOMETER AT SOUTHALL.

many of us have yet to be persuaded that its valuable products are more important than the romance of a flickering fire. It has been suggested that the ordinary open fire emits a ray that is of some health value. This is by no means impossible, for science has yet to explain the connection in this world between heat, light, and life. Coal is a substance that seems little appreciated. It differs only in physical formation, in some of its types, from the carbon of which diamonds are composed. Even the result of its combustion to carbon dioxide is used in refrigerating machinery ; its services to mankind may as yet have scarcely begun—in the new light of chemical and physical discovery.

CHAPTER V

CHEMICALS IN THE KITCHEN

We generally think of chemicals as something kept in the laboratory, but as a matter of fact we conduct quite a number of chemical "experiments" in the kitchen every day, and certainly use a large number of chemicals which are also to be found in every laboratory. It is a mistake to think of chemicals as horrid things which are only kept in chemists' shops and used by scientists. We need them very badly in the course of our ordinary life. Technical people employ chemicals, not because they like to dabble with strange things to produce weird smells, but because they are concerned with work that affects us all in our homes.

Perhaps the one chemical that is always to be found in every kitchen and on every dinner table is salt. It is in every laboratory too, under its scientific name of sodium chloride, and it differs very little from the salt we use daily, except in purity. The impurities in our " eating " salt are purposely added for reasons of general utility. The scientist does not use the term "salt" in application to sodium chloride, for this is only one of many " salts." He applies the term to the product of any acid with any base, and to

him Epsom-salt (magnesium sulphate), or washing soda (sodium carbonate), are just as much salts as sodium chloride.

Salt is added in small quantities to almost everything we eat. This is probably because we believe it " brings out the flavour," but it is also necessary for chemical reasons. If human beings were completely starved of salt they would become gravely ill and suffer great pain, although it happens that salt occurs so widely in vegetables and other foods that it would deliberately have to be extracted before much damage was done. Salt is necessary to various bodily processes, including the manufacture of the hydrochloric acid which is present in the digestive fluid. Salt exists in both our blood and in our perspiration, it can be tasted quite readily in both instances.

We feel thirsty when, after perspiring—which we do all the time, even if it is not visible—the concentration of salt in our blood passes a certain point. We require water to drink, and by this means the concentration is immediately lowered. You have probably heard that if people who are shipwrecked and left in an open boat without fresh water drink salt water, they go mad, or that it is better to drink no water at all rather than drink from the sea. The explanation is simple. It is concentration of salt that produces the excessive thirst, and if more salt is consumed the thirst eventually becomes so much worse that the nervous system is completely deranged.

The opposite of this case occurs in people who are " salt hungry." Nowadays this is only common

in native tribes, who have no natural store of salt and obtain very little by their normal diet. When they come across salt, those in this condition will eat a handful, just as we should eat sugar. Some natives who get little salt find sufficient in the meat they eat, the importance of this condiment and food being shown by the fact that in countries such as Abyssinia it becomes a form of money.

When we perspire we lose a certain amount of salt, so that athletes and furnace men may often need more salt than other workers. This is said to be one explanation for the popularity of foods such as salt fish and meat in industrial towns where a large number of men work under high temperatures. A furnace man may perspire several quarts a day, and has to drink a great deal of liquid to replace that loss. This liquid requires salt to maintain the blood concentration. It is probable that certain types of cramp experienced by athletes are due to lack of salt.

Very fortunately this essential article of diet is present in large amounts all over the world. It does not have to be manufactured like washing soda; it is already there for our use. If we had no other source, the sea could keep the whole world comfortably in salt. It has been calculated that there are 4½ million cubic miles of salt dissolved in the sea—a volume equal to that of the whole continent of Europe, and enough to fill all the salt cellars of the world for thousands of years.

In practice, a great deal of salt is obtained from the

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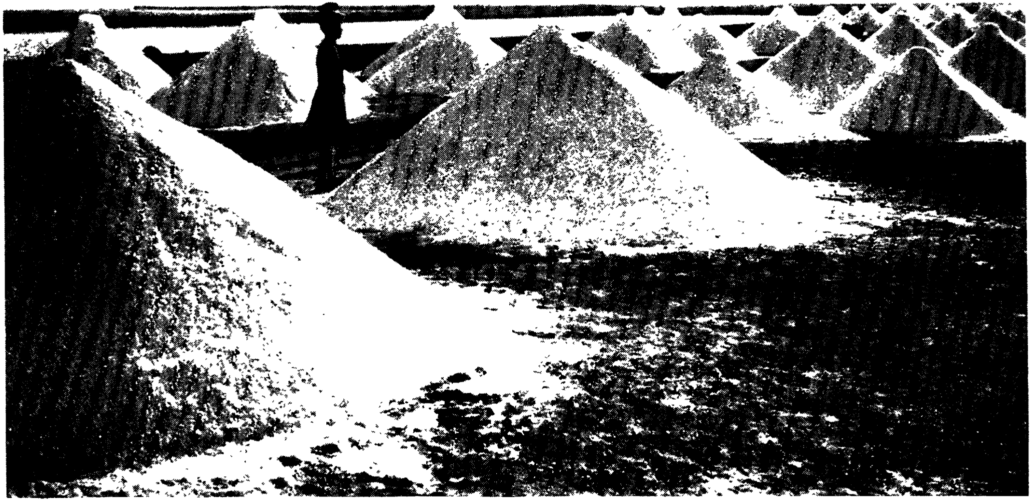

Photo Keystone-Underwood.

METHOD OF OBTAINING SALT IN INDIA.

(The salt has been obtained by evaporating salt water in " pans.")

sea, some of it by evaporation by the heat of the sun. The concentration of salt in the sea varies very surprisingly in different places and at different depths. In the Black Sea, for example, there is only 1.75 per cent. of salt, while in the Red Sea there is nearly 4 per cent. The Dead Sea, of course, is very salt. So great is the amount in solution that it is impossible for a swimmer to sink, even if he attempts to do so. This particular sea reaches a concentration of 25 per cent., but it is not all the table salt we know. The Dead Sea is estimated to contain thirty thousand million tons of salts, much of which is magnesium chloride and various salts of potassium. An industry for the recovery of these salts has now begun, potassium salts being as valuable to agriculture as is sodium chloride to the kitchen.

The manufacture of salt really consists of its purification. The raw material is always a solution of salt with other chemicals in water. In the case of sea water it is only necessary to evaporate the liquid; but it is not always convenient to obtain salt from the sea, and much of the world's supply is obtained from mines. Great layers of salt were formed thousands of years ago, and it can be mined in much the same way as coal, afterwards being dissolved in water for purification, or even dissolved in water underground to be pumped out as brine. In this brine there are certain undesirable impurities, principally salts of lime and magnesium. These are precipitated by adding milk of lime, when insoluble carbonates are formed.

The purified brine is evaporated, generally by steam heat. In evaporation a very ingenious method is used called " multiple steam evaporation." As is well known, the boiling point of water is not constant, but depends upon its pressure. Water boils at a much lower temperature at the top of a mountain, where the pressure is lower than at sea-level. By reducing the pressure in successive evaporating pans the unwanted water driven off as steam can actually be made to provide the heat to evaporate the salt in the next pan. Thus in the first pan the steam is driven off at normal pressure and is conducted to the second evaporating tank where the pressure is lowered, with the steam from the first at a sufficiently high temperature to evaporate the brine. The steam from the second pan is cooler, but still hot enough to evaporate water in the third pan where the pressure is even lower. By this means one ton of coal can be made to evaporate enough brine to yield five or six tons of salt, whereas under the old method of straightforward evaporation the yield was only about two and a half tons. It is the ingenious use of the laws of physics in such ways as this that has brought salt and other chemicals within the reach of every one.

When salt is obtained by the evaporation of natural salt water by the sun, it is run into shallow pans and several months may be required for its final evaporation. The pans are made shallow in comparison with their size, for the speed of evaporation depends upon the area of surface exposed. The

greater the surface in comparison with the total volume, the quicker the evaporation. It is for the same reason that tea is put into a saucer when we wish to cool it quickly!

In these large pans salt is left in great solid masses to be dug out by mechanical shovels ready to be carried away. The next treatment is the same as with any other kind of brine, the purified salt eventually being ground very fine or allowed to remain coarse according to the purpose for which it is required. The salt used for preserving fish is very coarse and contains about 5 per cent. of impurities which do not matter for this purpose. Table salt is much purer, but small quantities of other chemicals are generally added to prevent the salt becoming damp, when it is difficult to pour through a container or appears dirty in a cellar.

Salt dampens by a process called deliquescence. When certain crystals are exposed to the air, the moisture in the air associates with them. No chemical reaction takes place, the water being added as what is known as "water of crystallization." Sometimes this goes so far as to liquefy the larger crystals. Ordinary salt usually contains a small percentage of calcium and magnesium chlorides which have not been removed, and these are the crystals that deliquesce. To prevent this effect, very small quantities of either sodium carbonate or trisodium phosphate are added to table salt. These are quite harmless and tasteless in the salt while serving to keep the fine grains separated.

When salt is added to potatoes during cooking it is not only to alter the flavour, but also to change the boiling point of the water, so that the temperature at which cooking proceeds is higher. A solution of salt in water boils at a temperature higher than that of pure water. In the case of a saturated solution, that is, a solution that will not dissolve any more salt, the boiling point is nearly 110 degrees centigrade, whereas ordinary water boils at 100 degrees.

Some people heat water when it is desired to make it dissolve more salt. Now, while most crystals dissolve more freely in hot water than in cold, this does not apply to salt, which dissolves very little more salt at boiling point than at freezing point.

Salt is tremendously important to us in the kitchen, and if any reminder is needed we have it in the word "salarium," which is sometimes used in the sense of a payment or salary. Salt was known to be important even to the ancient Romans, and they made officers in their armies a special salt allowance which was called salarium. Eventually the salt allowance, like the "grog" in the navy to-day, was converted into a money payment, and hence our use of the word. But salt is also of great value in the manufacture of other useful chemicals, notably glass, chlorine, and sodium carbonate, where it is essential. Only a small part of the twenty million tons of salt manufactured every year appears on our dinner tables.

This "common salt" is one commonly used in our kitchens. Did you realize that you also had an acid on your larder shelf? Perhaps you have several,

but most certainly there is vinegar, which is really dilute acetic acid. Pure acetic acid such as the chemist uses would be of little use in the kitchen, for it is a poison and burns the skin, but vinegar is essential for preserving certain vegetables as pickles. There is about 5 per cent. of pure acid in vinegar; this is quite sufficient to give it an acid reaction.

The method by which vinegar is manufactured is interesting. Even for a long time after vinegar was being made on a large scale no one understood how it was made, and it was not until 1864 that the great Pasteur showed that it was the action result of a micro-organism, the *bacterium aceti*, although he had previously guessed at the truth. The starting point is a dilute solution of alcohol. In wine-making countries, such as France, this is obtained as a by-product, but the formation of "malt vinegar" is begun by extracting malt with warm water. The liquid is run off and cooled by a refrigerator, after which it is fermented with yeast so that the sugar is converted into alcohol. Yeast is really a group of simple plants that reproduce themselves very rapidly. It produces a group of substances known as enzymes, and we are discovering every day that these chemicals are most wonderful. They bring about chemical changes and play a part in many of our bodily functions. One enzyme called pepsin is essential to digestion, another called ptyaline is present in our saliva, and another, rennet, you all know for its ability to curdle the milk for junket.

The alcohol for our vinegar is produced from

sugar by the action of an enzyme called zymase, the yeast is afterwards skimmed off and the remaining liquor stored. It is then poured into a vessel which has a double bottom. In this bottom is a collection of beech shavings or similar material which has been itself soaked in vinegar. The alcohol liquor trickles through very slowly and at the same time is allowed plenty of air. Oxygen is added to the alcohol and vinegar produced. When the vinegar is from wine alcohol, a slower method is used, in which the liquid is poured into casks containing beech shavings impregnated with vinegar. The bungholes are left open to allow air to enter, and after some months the vinegar is ready. The first process is now generally preferred, because it only occupies two or three weeks.

Good vinegar has a rather pleasant aroma, due to the presence of salts of alcohol. Not all the alcohol is converted into acetic acid, very minute quantities being affected by acids to produce ethereal salts, "salt" being used in the chemical sense. Such substances have nothing to do with common salt, but are the result of an acid acting upon a base, in this case alcohol. These salts are the basis of many modern synthetic perfumes.

Although acetic acid in its pure form is never seen in the household, it is important in industry. It becomes a solid at quite moderate temperatures, is quite colourless, and with lead forms sugar of lead, or with copper, verdigris. The colour of vinegar is due to impurities, and, because most people like

rather a dark vinegar, colouring matter such as burned sugar is sometimes added.

A chemical widely used in most kitchens is washing soda. Technically known as sodium carbonate, it serves in the household for all kinds of heavy cleaning. Washing soda is made from common salt, and it is prepared in several different ways.

You may have noticed that after some time, washing soda crystals grow little white encrustations on the transparent crystals, which means that the crystals have given up some of their water of crystallization. Ultimately only a white powder is left. Washing soda, like salt, has peculiarities about dissolving in water. Its solubility increases up to a temperature of about 90 degrees, after which it falls, and boiling water dissolves much less soda than moderately warm water. Housewives often waste gas by using boiling water for soda, just as they turn on a gas flame so high that its heat cannot all be absorbed by a kettle in the time available.

Bicarbonate of soda figures in most kitchens. It is a great standby of dyspeptics for alleviating indigestion, for it is a strong "anti-acid" or alkali, and neutralizes acid. In the kitchen it will be found in baking powder where it is mixed either with acid potassium tartrate, tartaric acid, or cream of tartar. Baking powder—which, of course, is mixed with "self-raising" flour—is a substitute for yeast. When the constituents become moist they react together to release carbon dioxide, and this "raises" the dough in much the same way as yeast. As a rule a certain

amount of starch or flour is incorporated in the baking powder to prevent the reaction taking place before cooking begins. Carbon dioxide is the same gas that we exhale from our lungs, or which comes from the exhaust pipes of motor cars and the domestic chimney. An excellent example of a kitchen gas factory that works in every home.

Amongst the other interesting chemicals that are commonly used are flavours, such as vanilla. Probably to-day the majority of these are synthetic. There is a great deal of misunderstanding over this word synthetic, which is sometimes used very loosely, almost as a term implying poor quality. Strictly, the term should only be applied to chemicals built up or synthetized in the laboratory which are the same, except in the method of preparation, as those found naturally. For instance, synthetic quinine is the same chemical as the natural quinine produced from chincona bark. The reason why drugs, flavours, and perfumes are made in the laboratory instead of being extracted from natural sources is that it is sometimes cheaper and that often there is not always enough of the natural product available. In the case of quinine, the output of the natural drug is not nearly sufficient to meet the needs of the millions of malaria patients.

The term synthetic is also applied to certain substitutes. Artificial is another word used in the same way, as in the case of artificial silk. In practice, artificial silk has nothing at all to do with real silk, except that it resembles it in some ways. Chemically,

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[*Photo: Keystone-Underwood.*

IN THE STORAGE CHAMBER OF A SCOTTISH ICE FACTORY.

it is an entirely different substance, and it is not a "substitute." It is a great pity the term "artificial silk" was ever coined, because it implies something inferior. The word "rayon" is now used, and is a far better description. The expression "real silk" has no meaning, for all the silk we use is real. We have found no way of synthetizing silk, nor are we likely to do so at present.

In the case of some perfumes, the odour is due to the presence of a certain chemical in the flower, and it has been possible to build up this material synthetically in the laboratory much more cheaply than it can be extracted. Here the term synthetic is, perhaps, rightly applied. It has been found recently, however, that natural scents, although they may owe most of their odour to one chemical, consist of a mixture of substances, many of them only present in very minute quantities. The synthetic scent lacks these other compounds, but the perfume is accurate enough to deceive the human nose. It might not so readily trick the more sensitive sense organs of insects.

Two hundred years ago it was believed that there were thousands of chemicals which could only be produced by unaided nature. Chemistry is still sometimes divided into "inorganic" or "organic," and the foundation of organic chemistry, as we know it to-day, was laid when it was found possible to make urea in the laboratory. Even after this time it was still thought that all scents and flavours were "natural." Perkins, who discovered synthetic

dyes, found that coumarin could be prepared from salicylic aldehyde, showing that these "natural" substances might be prepared synthetically; for coumarin is the substance to which woodruff and other plants owe their fragrance. A few years later vanillin was prepared in the factory, the first of the synthetic flavours. Vanillin is the substance which is extracted from the vanilla bean and is used in such things as custards and ices. To-day, vanillin is not prepared by complete synthesis from its constituent elements of oxygen, hydrogen, and nitrogen, but from oil of cloves. It may seem strange that this pleasant tasting flavour is prepared from cloves, but the change is brought about quite simply by adding oxygen to eugenol, which is the largest constituent of oil of cloves.

A large number of flavours and perfumes are prepared from "ethers"—substances that are produced in the manufacture of alcohol. Pineapple flavour in sweets may be due to the chemical ethyl butyrate, and so on. The "essential oils" are definite chemicals, some of them with rather fearsome names, such as allyl isothiocyanate, which is the essential oil of mustard. When the oils are prepared from the natural materials they are secured either by distilling, so that the oil separates out from the moisture, or by expressing the plants with a solvent such as alcohol or petroleum, and afterwards distilling. Really good essential oils, especially for perfumes, must always be expensive owing to the large quantities of flowers that have to be treated.

Many pounds of roses are required to make a sprinkling of attar.

The search for synthetic products has been stimulated by their high value, and many perfumes have never been near the flower they successfully imitate. Lily of the Valley, for example, may be a chemical called terpineol, prepared from turpentine oil and nitric acid. Rose owes its scent to at least two chemicals, and the synthetic perfume contains geraniol and phenyl-ethyl alcohol. In many cases the synthetic products are built up from coal-tar derivatives. There is one strange fact in connection with synthetic compounds that is worthy of mention. Some of them respond perfectly to all chemical tests during analysis, but can be detected from their natural prototypes by the manner in which light is affected when passed through their crystals. This is also the case with some of the products of human digestion when in contact with the naturally formed hydrochloric acid of the stomach. Sea water can be analysed very carefully, but if manufactured is unable to support the life of many fish. Much the same conditions apply to artificially made air.

It may seem surprising to refer to margarine as a common chemical found in the kitchen, but this very useful butter substitute, although prepared largely from natural products, is purely synthetic. It is one of the few cases in which chemists have prepared a food at all. In many other instances they have shown how food can be preserved, but they have not " invented " foods. Margarine was pro-

duced deliberately to act as a substitute for butter. Just as food preserving was invented as a consequence of Napoleon's wars (he said an army marched on its stomach, and wished to provide supplies which could be carried in a knapsack), so margarine was thought out as the result of the Franco-Prussian War. A prize was offered for a butter substitute, and margarine was the result. It has become amazingly popular, and during the war almost entirely took the place of butter. Whatever prejudices there may have been against it were overcome, and although to-day most of us can afford to eat at least some butter, nearly every home uses margarine, if only for cooking.

In many nourishing qualities margarine is often equal to butter. It contains much the same chemicals. The question of flavour is largely "personal"; with some people it may depend upon their not knowing that it is margarine. But as margarine is prepared chemically and undergoes heat, it does not contain the vitamins of butter, and for this reason it is not a perfect substitute. We could eat it instead of butter as far as food values are concerned, but we should have to seek the vitamins brought to us in butter elsewhere. Possibly, in time, these may also be added artificially.

Margarine is made either from animal fats or from vegetable oils. In certain animal fats the same chemicals are to be found as in butter fat. These chemicals are called glycerides and are a combination formed by the action of oleic, stearic, and other acids

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[*Fox Photo.*

GIRL WORKER IN A MARGARINE FACTORY.

on glycerol. The margarine maker obtains them from beef or mutton fat, which is carefully washed and then chilled before being finely shredded for melting down with water. From this is expressed the oil, which is without smell or taste. Colouring matter can be added, and generally it is the same vegetable colouring matter as is added to butter to give it the appearance which purchasers seem to like. A comparatively small quantity of prepared milk is added. The milk is sterilized, soured with a bacteriological culture, and the mixture then churned for about one hour. The margarine in the making appears as lumps of fat floating on the liquid, which is ultimately drained off. Other oils or fats are added to give the right consistency. It is interesting to note that the chemist has even studied in detail conditions appertaining to the place of export. Margarine destined for a warm climate is given a slightly greater " thickness " and a higher melting-point than margarine intended for a colder part of the world.

In order to make the margarine resemble butter as much as possible, various substances are admixed. Milk-sugar and casein, for example, are added to make the margarine capable of browning and frothing like butter, but no preservative is added, this being recently forbidden by law. Salt is sometimes used, many people preferring a salty flavour. After this last process, it only remains for the margarine to be allowed to set, when the water is squeezed out of it and the finished material is ready for packing.

It is occasionally suggested that because margarine is in its way a synthetic food it is "full" of chemicals or impure. Nothing could be more mistaken. Margarine is hardly more "chemical" than many other foods. Everything we eat is a chemical or mixture of chemicals, and that these are naturally produced is no guarantee of purity. Indeed, the contrary is often the case, because of the difficulty of removing impurities from natural products. Drugs prepared from "herbs" usually contain other substances and cannot be so accurately estimated and dispensed as those prepared synthetically. In the case of margarine, the strictest hygiene is observed. This is required by law, but in these days manufacturers seldom need the law to teach them the importance of cleanliness, and it is usual to employ chemists, who conduct tests at every stage. A single mistake might mean the loss of many hundreds of pounds, so that a combination of human and mechanical observation methods is adopted which renders any serious error a matter of extreme improbability.

Both the kitchen and the human body are chemical factories, or even electricity generating stations, on a most complicated scale. The modern dietician investigates not merely the nature of a food as it is consumed, but the resultant effects upon those key glands that appear to control the entire functioning of the system. There are many cases where the physical condition of a substance, as apart from its chemical composition, is vitally important. It never follows that because such materials as alcohol are

produced internally they can be administered from an outside source. Research is teaching us that the food supply of the future may be based upon principles that at present are almost unknown in the average home.

CHAPTER VI

HOW ELECTRICITY IS USED IN OUR HOMES

EVER since the war the whole of Great Britain has been covered by what is called a " Grid." The outward and visible signs of it are the great steel pylons which are now seen supporting cables almost everywhere we go. We may argue as to whether they have a certain dignity or beauty of their own or whether they are a blot upon the countryside, but we rarely consider how vitally they affect our lives. We read that they carry electricity at a pressure of 132,000 volts and decide that we will keep well away, but we think of them mostly as conveying electricity to great factories or workships for power purposes rather than as bringing electricity to our house lamps that require only 240 volts of pressure.

Now, although the Grid is of great value to industry and has resulted in many factories changing from steam power to electricity, it is also designed to bring light and heat into every home. It was argued that it would be better to make electricity in large quantities where it was easy to produce and distribute than to generate it in thousands of little power stations. The argument is common sense; in these days few

could conveniently keep a cow to supply the morning milk, a pond for fish, or a little patch of wheat for bread. We have huge dairy farms, great fields of wheat, and bakeries. It seems curious that so many years had to pass before the same principles were applied to electricity, and the complication of hundreds of different voltages abolished. Even to-day there are still places where one side of a street has alternating current at one pressure and the other side direct current at another voltage altogether. Apart from the inconvenience of converting electrical apparatus during moving house, these variations make it necessary for manufacturers to construct many different types of lamps and motors, so that their charges have all to be raised accordingly. Standardization is a great help to economy.

The Grid system, which probably supplies your house with electricity, is too vast to describe in brief. It is still growing. More than fifty million pounds have been spent upon it, and Britain has been made a network of some 4,000 miles of high-tension cables. The great principle is that electricity shall be generated in large quantities at convenient places. At the Battersea Power Station the energy of 2,000 tons of coal is converted into electricity every day through the medium of boilers and dynamos. In Scotland water is carried many miles through huge concrete pipes to turn turbines that are coupled to dynamos. In Newcastle three million pounds was spent on a power station, and these are merely typical examples of many. The vastness of it all becomes the more

surprising when you learn that the result may be a reduction of a penny or twopence a unit on your electricity bill. But that is by no means the whole story, for the Grid has brought electricity to many places which before had no electric light at all, or, at best, a very inadequate supply.

If you could visit one of these generating stations where the electricity that lights your lamps is made, you would probably be struck as much with its cleanliness as with its size. The huge steam turbines are enclosed in steel cases, all around are tiled and concreted walls, with shining steel railings. The tremendous output of power is controlled by banks of switches, and one man could, by a simple movement of his hand, switch out a million lights in a hundred thousand homes. Sometimes a " black out " like this does occur, due to a failure, but generally the turbines continue to turn the dynamos year in and year out. Individual dynamos are switched in or out of their circuit according to the demand for current, the turbines and dynamos being, of course, occasionally stopped for cleaning or repair. Perhaps you have noticed, in the early morning or at dusk, a slight flicker in the lights for a moment ; this is sometimes due to the " cutting " in or out of a dynamo.

Whenever we glance at our windows to see if it is dark enough to switch on the lights, we seldom pause to think that a million other people may be doing the same thing, or that in offices and streets the lights are being put on one after another. But the con-

troller of the generating station has to make these allowances. He knows from experience when to anticipate an unusual load and is prepared for it, so that output is always equal to demand. He watches dials on which are registered the call for current and brings in additional power as required. The " brain" of a huge generating station is rather like the bridge of a modern liner. Through glass windows the engineers can look down on the generators, while a maze of dials tells each operator the story of every moment. Telephones connect one department with another. The switches themselves, or circuit-breakers, are not like the little brass switches in your home. They have to pass a tremendous current, and often work under oil to prevent sparking.

When an electric current is sent along a wire it loses strength. The amount of loss depends upon various factors, but generally the higher the voltage the less the loss, having regard to the size of cable that can be used in practice. It is the sectional area of the wire that determines the amount of current that may effectively be carried. Very heavy wires would be vastly expensive, so, in the case of the Grid system, the high pressure of 132,000 was employed for all long distances. Before the current is brought to your home it passes through a transformer which reduces this voltage. The standard pressure for the Grid is 230 at 50 " cycles." The current is alternating, that its to say, it flows first in one direction and then in the other. If it alternated slowly, you would notice your lamps flickering owing to the

sudden dying away and increasing of the current. But when this occurs fifty times in a second, the filament has little time to cool and the light appears as steady as when the current is "direct." It is this alternation that enables a simple clock to be run from the mains, by causing each change in current to pull round a wheel connected to the clock hands.

Electric current is probably brought to your house from a sub-station. In some places the transformers are in the open and can be seen from the roadway. They are very much like the transformers in a wireless set but on a far larger scale. Apart from the thickly covered wire that would be needed, it would be unsafe to use a voltage of many thousands in a house; 240 volts is comparatively safe, and so a certain amount of efficiency has to be sacrificed. For the sake of protection the wires are enclosed in iron or lead conduits as well as being insulated in the ordinary way. There is little danger of their becoming damp and the insulation failing, which might result in a "short-circuit," or in the current taking an easy and shorter path than that intended.

Before the electricity reaches the house meter there is a main fuse which would "break" under any very unusual load. In practice, this main fuse very seldom melts. After the meter, the current passes to another main fuse and then to a fuse-box, where each separate circuit has its own fuse. The object of a fuse is to protect the house wires from becoming overheated and thus resulting in a break which would be difficult to find, or a fire. The fuse

wire is generally laid over a china container which is easily inserted or removed. This wire consists of a metal alloy which melts when a current of more than a certain strength is carried. The melting of the wire breaks the circuit and avoids any danger. Sometimes when a fuse melts and the right wire cannot be found, a piece of ordinary wire or even a hairpin is inserted. This is dangerous as the wire will not fuse at the same low temperature and a serious fire may result. Replacing a fuse is a simple operation, the only precaution necessary is first to switch off the current at the main.

From the fuse-board the current goes to the various lampholders. Gas-filled lamps are commonly used at present. Electric light is really electric heat. The light is emitted by a fine metal wire which offers resistance to the passage of the electric current. The only difference between an electric lamp and an electric fire is that the filament in the lamp is thinner and so chosen that it emits a bright light at white heat. Not more than a very small percentage of the energy of the electricity consumed by your electric lamp is turned into light. All the rest is wasted as heat.

The modern lamp has been evolved from the carbon lamps of Thomas Edison and Sir Joseph Swan. Electric lighting was not really practicable until the invention of the dynamo provided a source of steady and continuous current. The first electric lighting depended upon the arc—the light emitted when a powerful electric current passes between two

incandescent electrodes. This light is very bright, but the disadvantage is its intense heat and the gradual consumption of the electrodes. There are many devices for keeping the carbons always the same distance apart, regardless of their actual length, but electric lighting in private houses on a large scale would have been almost impossible without the invention of the electric lamp. Owing to the ease with which the small and intensely bright spot of light produced by an arc lamp may be focused, the system is generally employed for cinema or similar projection purposes.

The problem that faced the inventors of filament lamps was the discovery of suitable material for this filament. It had to emit a bright light and yet must not burn away too quickly. Research on this subject is still devoted to a similar end, although another great object is now to reduce the current consumption as much as possible; in other words, to secure as much light for as little electricity as may be used. The efficiency of an electric lamp is measured by "lumens," a name given to the ratio between lighting power and current consumption. Its brightness is still compared with that of a standard candle.

Early electric lamps were fitted with carbon filaments, made by burning cotton. They gave some light, but it was not until Edison found that the filament would not burn away if the lamp was exhausted of air that real progress was made. Combustion requires oxygen, and, deprived of its oxygen, the white-hot filament no longer wasted so

quickly. Even in the vacuum lamp a filament did not last for ever however, for carbon can evaporate. But carbon lamps were the first serviceable type, and although to-day their light seems very yellow, they are useful in places where rough handling or vibration is experienced.

Later came the invention of the metallic filament. Various metals have been used, but tungsten is now almost universal. A fine wire is drawn and suspended inside the lamp. The filament may be coiled or doubled to give a greater length in a small space. Naturally, the higher the temperature to which the filament is heated the greater the light, but the temperature is never permitted to rise beyond a certain figure, well below the melting point of tungsten, in case the metal should evaporate and blacken the bulb. Tungsten has been chosen as the most suitable material because it is ductile and can safely be heated to a temperature of over 2,000 degrees Centigrade, very much higher than in the case of carbon.

In attempts to heat the filament without blackening of the bulb, experimenters tried filling the lamp with one of the inert gases instead of leaving a vacuum; this avoids the difficulty of extracting the air which adheres to the glass surface. Gas-filled lamps are now commonly used, and are able to give a very bright light owing to the temperature to which it is possible to heat the filament without burning. Argon, one of the rare gases of the atmosphere, is often used as a filling. With gas-filled bulbs more

energy is usually required to heat up the filament, and with very low-powered lamps it is sometimes cheaper to use the vacuum type, but if one good bright light is required in a room the gas-filled lamp provides it most economically.

For reasons of economy and of maintenance it is most important that a lamp should always be used of the exact voltage to suit the pressure of supply. A variation of even ten volts may mean waste. If the lamp is of too high a voltage, the emitted light will be seriously reduced without a proportionate saving in current. If a lamp is of too low a voltage it will burn out long before its proper life. The " life " of a lamp is the period for which it gives the light for which it is rated. This is at least 1,000 hours with a good make of lamp run at the right voltage, and after this period the lamp will not cease to give light, but there will come a time when the light is poor but the current consumption remains at its full value. The reason why lamps are best cleaned when burning is that the wire filament is hot and less brittle; damp cloths should not be used unless the current is off. Tapping a lamp gently will sometimes unite the ends of a broken filament, for the sparks as the ends touch may be enough to weld them together.

The cost of supplying a lamp depends upon the price paid for a " unit," which may be between a fraction of a penny and sixpence, or even more. These units, or Board of Trade units, to give their full name, are not arbitrary figures, but represent the amount of work done by a thousand watts acting

for one hour. This makes it easy to calculate how much an electric motor costs to run. If, for example, a vacuum cleaner has a $\frac{1}{4}$-h.p. motor, it can be worked for just over five hours for the price of one unit. A refrigerator with a $\frac{1}{8}$-h.p. motor would run about eleven hours, and so on. In most districts the price for electricity used for " power " is very low. To calculate the cost of running a lamp the number of watts is multiplied by the number of hours. For instance, a 100-watt lamp run for ten hours will consume exactly one kilowatt, and the cost per hour will be one-tenth the cost of a unit. By adding the wattage of your lamps together you can easily calculate what it costs to keep the house lighted, and also what you have wasted when you forget to turn out a light at night. A watt is the power unit for electricity and is obtained by multiplying current by pressure, that is to say, amperes by volts.

Gas-filled and vacuum lamps are likely to be used in private for some time, but in our streets we have many new forms of electric lighting. The brilliant red of neon lighting is now well known. In this case another of the rare gases of the atmosphere is used, which, when a discharge at a high voltage is made through it, glows red. The light comes, not from a filament, but from the gas itself. By using other gases or mixtures of gases it is possible to produce nearly any colour.

In an effort to achieve " daylight " lighting for the sake of speed and safety in busy streets, lamps using mercury and sodium vapour are now being

installed. These give an intense light, which often approximates more closely to daylight than ordinary electric lighting. At present they are hardly practical for domestic purposes, although recent experiments have produced a small mercury vapour lamp which gives a light about two hundred times as great as that of an ordinary electric lamp of the same size. These hot cathode lamps work at a high temperature, and sometimes have to be enclosed by quartz instead of glass.

The ideal to which we should work is a lamp which gives great light and no heat. Fireflies may have mastered this secret, but real "cold light" has yet to be produced commercially. It is possible to produce "cold light" in the laboratory. If luminol and sodium hydroxide are dissolved in water: by adding potassium ferrocyanide with hydrogen peroxide a bluish-green light is emitted. Unfortunately the luminol becomes oxidized and more has to be used. The cost of this lamp would be about £60 a candle-power an hour. The firefly makes his own chemicals, and until we can find a way of producing the necessary materials at an almost negligible cost we are likely to continue with electric in our home.

Although electricity is a very safe method of transmitting power, quite a number of lives are lost in private houses each year by accidents with this form of apparatus. Most of them are due to ignorance of the first principles of safety. A shock occurs when the body becomes part of an electric circuit.

Repairs of any kind should never be begun until the switch is off at the main, but as soon as the circuit is broken at this point work can be carried out on any part of the wiring. Always make sure that all joints are tight. A loose join at a lampholder or plug may mean heating and danger. But especially be careful of touching anything electrical when the hands or body are wet. Many bathrooms now have the switch outside, so that there is no possibility of touching it when the feet are damp. Ordinary water is a good conductor of electricity and makes a circuit where, with dry hands or feet, no appreciable current could pass. It is now obligatory to have the bathroom switch, if not outside, at least in such a position that it cannot be touched by any one in the bath. If a bathroom is fitted with an electric fire, be very careful. It is best not to take any portable electric apparatus into such rooms, but it is worth mentioning that the treatment for electric shock is similar to that for partial drowning.

Perhaps the strangest of all things in connection with electricity is that no one actually knows what it is. We can study its effects: it was the jerking of a frog's leg when put in circuit with a battery that led to the discovery of electricity; we can cause it to produce heat or light, but no one has ever succeeded in "separating" electricity. Indeed, it now appears that we ourselves and all matter are no more than particles of electricity in motion.

For this reason it is convenient to adopt some workable simile and to compare electricity with

water under high pressure, trying always to escape from its conductors. The pressure of the water represents the voltage of a supply system and the amount of water flowing is compared to the current or "amperes." Unlike water in a pipe, electricity seems to travel by a kind of infinitesimal vibration, and not by the actual movement of particles along the wires.

It was Faraday who discovered that when a wire is moved near the poles of a magnet a current is set up in the wire. In effect, this is the underlying principle of every motor or dynamo in the world. In an electric motor electricity is sent through a number of wire coils, and the electro-magnets so produced pull round other electro-magnets which themselves may be connected through gears to the wheels of a train or the fan of a vacuum cleaner. In a dynamo the coils are mechanically driven past electro-magnets, causing the reverse process to take place and making a difference in pressure between the ends of the wire, which in turn sets up a current in the coils. It is these currents that are used for light, heating, or other work.

Electric bells are very similar to motors, except that the current from a battery works as a clapper instead of causing a wheel to revolve. It is one of the most interesting phenomena of electricity in motion that if it is conducted round an ordinary coil, like a reel of cotton made of copper wire instead of thread, the flat ends of this coil become the north and south poles of a magnet. The magnetism can be made

more concentrated by putting a piece of iron or a number of iron wires into the core of the coil, and it is this core that is used to work the clapper of electric bells.

Attached to the "keeper" of the magnet is not only the clapper but a flat spring. When the "keeper," or armature as it is called, moves to strike the bell the spring moves with it and breaks the circuit, so that the striker flies back in readiness for its next stroke.

This is all quite simple, but the important point is that the current in the coils becomes pulsating. It is on or off alternately, and it is the effects of this pulsation that have led to the universal adoption of alternating current for all our main supplies, except those which are intended for electrolytical chemical work or similar cases.

Just as a current sweeping round a coil produces magnetism, so the change of magnetism produces a current at a pressure or voltage depending upon the number of turns of the coil. In practice, therefore, electricity is set in motion by spinning huge coils in proximity to electro-magnets, and the current is allowed to flow from these coils in alternate directions, as the direction in which the coil passes the magnet changes with every revolution of the armature. In this case the armature is the bundle of coils which is driven round near to the magneto by the steam turbine or whatever prime mover is being used.

This alternating current has many advantages

over rectified or direct current, because its pressure can be transformed without any other dynamos or moving machinery. Transformation is very easy. The alternating supply or " A.C." is taken to a coil over which another coil has been wound. Every time the A.C. changes its direction the " magnetic " or inductive effect also produces a current in the second coil at a pressure depending, as has been explained, upon the number of turns in that coil.

Supposing an alternator is connected to a coil with 100 turns, and round the coil in another having 200 turns, the pressure is " stepped up " in the second coil in the ratio of one to two. For long-distance transmission electricity can be transformed to high pressures only requiring thin wires, just as small pipes would carry water in quantities if the pressure was high, and upon reaching a city the pressure can again be transformed down to a safe pressure of 240 volts. In a radio set, where high voltages are needed, alternating current can most conveniently be transformed up to any reasonable pressure that is likely to be needed.

The uses to which electricity may be put have, as yet, been investigated to a very small extent. From electric furnaces, the electrolytic deposition of metals, the manufacture of chemicals, welding, and innumerable aids to domestic comfort, electricity is becoming the greatest asset of civilization. For medical purposes it is destined to be our greatest healer ; its part in the gland or fermentation processes of our bodily mechanism is only beginning to

dawn upon the world of medicine. Our knowledge of electrical power storage and capacity distribution is in its infancy : such problems as those of thought energy, or the very structure of matter itself, are undoubtedly electrical in their basic cause.

CHAPTER VII

ELECTRIC APPLIANCES

ELECTRICITY to-day is often the best housemaid; many of the tasks which our grandmothers had to perform so laboriously by hand are done for us to-day quickly and cleanly by electricity. In our "all electric" house there are probably at least half a dozen appliances, and even if the work is not all electrified, electricity is almost certainly serving you in some manner. Electricity in the home has been so simplified that it is possible to use it for a dozen purposes; even to cook and cool by it without knowing anything about electricity at all, except that certain switches must be pressed. This is a great tribute to the ingenuity of inventors who have made devices "fool-proof," and to engineers who construct them so that they are safe, but there is no doubt that an understanding of various electric appliances is of immense assistance to their effective use.

Perhaps the most widely used device, apart from a bell, is the electric iron, for in this case electricity is quite unrivalled. The iron heated by a fire begins cooling from the moment it is taken "off," and it is impossible to keep it at the constant heat which is so necessary for good ironing. Gas irons are efficient,

but the one disadvantage is that the products of combustion must enter the room; this does not apply in the case of a gas cooker which can have a vent.

In an electric iron the essential part is a wire or "element," which is usually wound round a sheet of mica or porcelain. This wire is of special alloy, similar to that used in electric cookers, and to prevent the heat escaping upwards, where it is not required, the hot wire is insulated by a sheet of asbestos or other non-conducting substance. At the bottom the wire is insulated electrically from the polished surface of the iron, so that there shall be no chance of a shock. All that is necessary is a connection by means of wire and plug to an electric "point," the heat of the iron being regulated by switching on or off. In some irons a thermostatic device is incorporated, so that when the temperature reaches a certain level the current is cut off, and switched on again when the temperature falls below a certain point. In yet another type two temperatures can be secured by setting the control.

Many people wonder how much current an electric iron consumes. An iron may vary between 300 and 500 watts according to size, that is to say, it consumes between three and five times as much current as a really "strong" lamp. With electricity being sold at a penny a unit, this means that an iron can be used for between 2 and 3½ hours for a penny. Power is, of course, voltage multiplied by current.

Electric irons are usually equipped with some

simple wire device for holding the flex firmly where it joins the iron. This is necessary, not only to prevent the flex becoming tangled, but also to prevent it becoming worn or loose. Loose electrical joints are always a potential source of danger, for sparking or heating may occur. Even if nothing more serious happens, the electric energy for which you are paying is wasted in useless heat by any bad contact.

Many different types of electric heaters are made for different purposes. They vary from shaving-pots, kettles, and electric coffee percolators to electric entrée dishes. In all the same principle is used. The heat is produced by the resistance of an alloy wire, usually wound round and round a carefully insulated non-conductor. The wire is placed at the bottom of the device, so that heat travels upwards, and the bottom is protected to prevent waste or damage to polished surfaces.

Another type of heater altogether is the immersion heater, in which the electrical heating device is placed directly in the liquid. In the case of kettles this is not so convenient as the enclosed filament, but immersion heaters are now often employed in boiling large quantities of water for baths or central heating. The " element " is then placed in a specially insulated water-tank, and the rather considerable consumption of electricity is offset by the great reduction in the price per unit which most companies make to large-scale domestic users.

Electric toasters are very similar to electric kettles, except that in this case the heating element

is exposed to the air, and the transmission of heat takes place not by conduction but by radiation. More heat may be wasted, but this is of little account in comparison with the convenience of making toast on the table as it is required.

An electric cooker simply consists of a series of heating devices. The heat is generally conveyed direct to the cooking vessels by conduction from a hot plate. Radiation plays a small part, except in the electric grill. For this reason iron or enamel saucepans are wasteful, and thin aluminium cooking vessels are more usual. Their shape is important, for efficiency depends upon good contact with the hot plate. A cheap saucepan may have a curved bottom, only a small part of which touches the flat plate. The base should be absolutely flat, or a certain amount of heat will be lost in transmission through the intervening air.

Electricity is energy, and, as such, can be turned into any other form of energy. In many of these domestic devices heat is required, but in others electricity is turned into mechanical motion. The commonest of these is the vacuum cleaner, which is now to be found in almost every home. The vacuum cleaner mostly depends upon suction, and this is produced by a small fan rotated by an electric motor. Only one-quarter or one-fifth horse-power is required, so that the vacuum cleaner does not consume a great deal of current. The partial vacuum is created by suction, and the air near by is carried into a bag, taking with it, of course, the small particles of dirt.

Some vacuum cleaners have also a brushing device, working off the same motor, which stirs up the threads of the fabric being cleaned.

Vacuum cleaning is not only a more labour-saving way of cleaning a room, but is often more efficient and healthier. However careful a sweeper may be, a certain amount of dust is sure to be brushed into the air. This is avoided with the vacuum cleaner, which, indeed, can be used to clean the air. By attaching a device to the " blowing " end of the cleaner a powerful current of air is available, and this can be used for drying hair, or even for blowing up an ordinary fire. Proper hair driers not only produce a current of air, but heats it so that it can absorb a greater quantity of moisture. A hair drier consists of a very small motor driving a fan to blow air through a heating filament of which the temperature can be controlled.

Electrical floor polishers have been made in which an electric motor driving pads performs the laborious task of polishing; electricity is also used to save the labour of hand-washing clothes and dishes. In the electric washing machine, a motor, more powerful than that required for a vacuum cleaner, rotates the clothes in a drum, or rotates a drum so that the clothes are constantly brought into intimate contact with soap and water. The motor has to be considerably geared down, and when the work of washing is completed, in some models, it is switched on to the wringer, through which the clothes are passed before drying.

An electric iron, in which the rollers are heated and turned by electricity, is also common in laundry work, but for the actual washing water it is not generally economical to heat by electricity, so that these machines are often connected to the main hot water supply. Washing machines are expensive, which explains, perhaps, why we do not find them in every home. But if the price of the machine is reckoned as a capital charge, the cost of working is no greater than that of employing a washerwoman, with the general convenience that the machine is not temperamental, does not require a cup of tea in the middle of the morning, and is never late. A machine needs no refreshments, but it does need oil, a serious omission in many houses which are equipped with every kind of electrical devices, but seldom an oil-can. Wherever there is movement between metal parts there is friction, and oil is the greatest preventative. Friction means waste of energy and wear. Oil prevents both. Electrical appliances should not be douched with oil, but the moving parts of vacuum cleaners, washers, and motors cannot be expected to run year after year without attention. The waste of energy that takes place through friction is perhaps not so important as the wear, which means eventual renewal of working parts.

There are many other electrical machines, from dish-washers to egg-whisks. The great factor that cannot be overlooked in any labour-saving device is that of time. For example, it probably would not be worth while for the average house to use an

electrical dish-washer, simply because of the time required to put it into action. There was once a very ingenious device for washing tumblers; according to the inventor it washed thirty tumblers, or it may have been three hundred, in a minute. This was perfectly correct. What had been forgotten was that it took nearly fifteen minutes to insert the tumblers, so that it would have been both quicker and cheaper to carry out all the washing by hand.

Electric sewing machines are now gradually taking the place of the hand- or foot-driven models. A small electric motor does the work, driving the flywheel by a belt. In order to regulate the speed a resistance or "rheostat" is provided. Usually this is operated by the foot, so that both hands can be free, and a touch of the toe enables the machine to be run at any speed. A "resistance" is usually a coil of wire made from iron or some alloy which does not act as a good conductor of electricity.

Very few houses to-day are without electric bells, but we seldom worry about their mechanism except when they cease to work. The electric bell is an interesting device, and as they are cheap it is worth while taking one to pieces and then to reassemble its parts. The small current required to work a bell may be obtained, through a transformer, from the mains, but it is more usual to employ dry cells. In the early days of electricity the only way in which charges could be obtained was from electrical machines or primary batteries. Until the invention of the dynamo, the accumulator was useless, for

there was no continuous supply of current to store. The primary cell is not really a very efficient " producer " of electricity, for it will only work for short periods, but for this very reason it is admirably suited to operate a bell, which is in action for short periods at intervals. After a bell has rung for several minutes, it will eventually cease to work. But after a time the battery recovers and the bell rings again. A dry battery will work for two or three years without attention in the ordinary way, and if a Leclanché cell is used it only requires filling with water or chemical at long intervals.

In the primary cell electricity is set in motion or " manufactured " by chemical action. In, for example, the Leclanché or wet battery a zinc rod forms one terminal, while the other is a carbon rod, usually situated inside a porous pot. The battery is filled with a solution of sal-ammoniac ammonium chloride. In a dry battery the arrangement is similar, but in this case the zinc forms the containing case, and the carbon rod is placed down the centre. If an old dry battery is pulled to pieces, it first discloses a layer of bitumen. This is merely used for sealing the cell. Next, upon stripping off the paper covering, is a zinc vessel. Inside this are layers of white and black paste, which consists of a mixture of manganese dioxide and carbon in the case of the black substance. Manganese dioxide is used, not because it has any particular virtue, but because it has no direct chemical action with the other constituents. The white paste is usually ammonium

chloride mixed with Plaster of Paris, water, and other materials. It corresponds to the solution of sal-ammoniac in the wet battery. Finally, in the centre is a thick carbon rod, to the top of which is screwed a terminal. The other contact is fixed to the zinc casing.

What happens when the bell is pressed is that the sal-ammoniac is acted upon by the zinc, and electric charges are liberated to collect at the terminals. As soon as the bell-push is released a reversed process takes place. Zinc, which has been formed into the chloride, is again deposited. This reversibility is by no means perfect. In the first place some ammonia is generated and escapes into the air, in the case of a dry battery, through the small glass tube which projects through the bitumen covering. But there is sufficient regeneration for the battery to last a very long time when it is used at intervals. It is the reversing process that explains why a bell, when "given a rest," comes into action again. But if the zinc rod from an old Leclanché cell is examined it is found to be very much eaten away. A new rod and a filling with more sal-ammoniac solution means practically a new cell.

The details of the bell itself are exactly like an electric motor in the principle of their electro-magnetic action, except that the armature oscillates instead of moving round and round. The magnetic force is produced in the usual way of passing a current through fine wire that is wound round an iron core. This " inductive " or magnetic effect is

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[*Photo Keystone-Underwood*

ELECTRICAL HEATING APPARATUS.

the method by which electrical energy can so easily be converted to mechanical movement. Whether it is a magnet attracting the iron armature to which a bell-striker is attached, or the huge armature of a 500 horse-power motor with its many magnetic poles, the electrical result is almost identical. As with a simple horseshoe magnet, like poles repel each other while north and south attract. In the bell the magnet alternately pulls or releases the clapper, and in the motor the north poles pull the south poles round one after another as long as the motor is running.

A great deal about electricity can be learned by mending a bell set that has ceased to work. First of all make sure that the bell push-switch is really making a good contact, then examine the dry cells or Leclanché battery and find out if it requires renewal. Examine the bell and see if any of the parts have corroded ; if the gap between the magnet and striker requires adjustment; or if the contact points are not touching clearly when the adjustment screw is moved. Generally the fault is to be found in one of these things and can be corrected in a matter of minutes. Very occasionally the fault lies in the wiring. Where there are a number of pushes in different rooms, working the same bell, an indicator is used in which a small flap drops to show which push is in action. These indicators also depend upon electro-magnetic action, and may be returned to position by means of a spring when the current is cut off. It is possible that the fault might lie with

a corroded terminal in the indicator, for, as with all these appliances, cleanliness is of real importance. Electricity in motion is a form of energy, and may therefore always be regarded as trying to escape to the earth or back to the universe as its natural storehouse.

CHAPTER VIII

GRAMOPHONES, WIRELESS, AND TELEVISION

DURING the early broadcasting of 1924 it was seldom realized that within twelve years every home in the country would have its own wireless set. It is, perhaps, not true that every home has its own receiver, but, if relay stations are included, very few people are without radio. Many houses have more than one apparatus, and they are usually of a very powerful type in comparison with the feeble crystal set of only a few years ago. Cost of equipment has also been reduced to an astonishing extent.

Few inventions have been so rapidly improved and exploited. Wireless is taken for granted, like hot water. Sets can be built at home without the least understanding of their working. Radio, indeed, is a technical subject, but, fortunately, it is not necessary to have a profound knowledge of mathematics and electricity either to enjoy the entertainment which wireless provides or even to appreciate many of the broad principles that are involved.

The " heart " of a modern wireless set is the valve ; it is one of the most remarkable examples of modern manufacture that such a delicate piece of apparatus, dealing with objects so minute as to be

invisible even under the most powerful ultra-microscope, can be produced at a price comparable with an ordinary electric lamp. Valves are of many kinds and are made in many shapes, but the process of manufacture is similar for every type. The greatest ingenuity has been lavished on automatic machinery for the construction of valves which are now made almost without handling. The operators do not have to be very skilled, and it is probable that many of the girls employed have no idea at all of what goes on inside the valves they build. The skill of the inventor has made it possible for valves to be mass-produced with a minimum of technical difficulty, and with the fortunate result that the owner of a wireless set does not find replacements to be disastrously expensive.

The first stage of a valve is the production of the "foot," a short glass funnel. This is fed by hand into a machine with the necessary wires and length of glass tube. The machine has a large number of holders, which pass before the operator in turn and, when filled, move on to pass before blowpipes. The glass is melted to exactly the right consistency, and as the holders travel farther the wires are pushed into the glass for pinching. In a short time the foot is complete, and it has been almost entirely made by machinery. The other parts of the valve are also machine-made. The grids are wound, cut to length, and the nickel anodes cut out. These are all brought together in the assembly room, where more machines are used to press the wires of the foot into exactly the right shape to receive the grid

and anode. The operator may only need to press a pedal to weld these junctions into place. The filament is fitted, and, after inspection, the valve is ready for fitting to its glass bulb. This is carried out by machinery, the bulb with the foot inside being turned before gas heaters so that it can be sealed and excess glass removed. The sealing is not complete, for the thin glass tube originally fitted into the foot makes an opening connecting the interior and exterior. It is through this tube that the valve is exhausted.

The removal of air is carried out by means of powerful pumps, and the temperature is raised to ensure any bubbles of gas being detached from the glass. Finally, the connecting tube is sealed by a flame which melts the glass. The valve has still to pass several stages of production, but these are mostly concerned with cementing the base, soldering the terminals, and finishing. One very interesting process is the final exhaustion of the bulb to produce a nearly perfect vacuum, for the best pumps are not entirely efficient. The valve is made, therefore, with a small piece of magnesium inside. After the connecting tube has been sealed, this magnesium is fired by an ingenious electrical device and combines with any gases left, some of the metal being deposited on the inner surface of the valve as a silvery coating. The "readings" of each valve are taken, and any that do not give the required results are rejected. The valve is then ready for its wireless set, and when it is considered that it costs only

a matter of shillings, it is easy to realize what inventiveness can do for quantity manufacture.

The most important part of a wireless set is, in some respects, nothing, for the vacuum is one of the most remarkable and useful " inventions " we possess. It helps us to reproduce music at a distance of a hundred miles; or, in the photo-electric cell, to control the movement of doors by light or to reproduce speech from a photographic film. We have to thank nothing for a very great deal.

Radio apparatus design has become a highly technical process, but this industry of valve manufacture is of special interest, even if for the fact that so many millions of people enjoy broadcasting without a thought of the technical labour involved, except to complain when replacements are necessary. A radio valve is too often classed with an electric lamp, although, in fact, it is an ingenious electrical device in which streams of electrons move at terrific velocities to serve our will.

The thermionic valve, or " tube," as it is called in America, is, as its name implies, an apparatus to restrict the passing of electricity in more than one direction. It consists essentially of a bulb containing a filament which is heated to cause it to send out a spray of electric particles, and a metal plate on which these particles can strike. Wireless ripples of electricity travel through space, and on being led to a valve are only able to move easily in one direction by the aid of the electric stream. In such a case the valve enables the radio waves to be heard in a tele-

phone, and is said to be acting as a "detector." When a "grid" is added to the valve between plate and filament, this metal grid can be electrically charged from outside batteries, and the impulses of "current" so much helped that they rise to a higher value than that of the received current. The valve is acting as an "amplifier," and the current from it can be taken to a bell, a loudspeaker, or any other device. Crystal detection replaces the detector valve by permitting electrical movements or wireless æther waves to pass in one direction only, but in spite of its freedom from electrical troubles it is often inefficient. Smaller and more lasting valves are being produced each year; it is a science all-important to radio, but as yet in a stage of partial development with a future that is literally illimitable.

Perhaps it is a testimonial to the quality of the modern wireless set that so many people believe they are listening to the sound made by an orchestra or to the voice of a speaker. It is not, of course, the actual sounds that they hear, but an electro-mechanical reproduction, in which a plate or core is made to vibrate in time with the original sound by the electricity passing through coils or magnets in the same fashion as in the case of an electric bell. The "wireless" music is just as much a reproduction as if it were that of a gramophone record. Ordinary sounds are vibrations in the air, and are generally produced by the vibration of something solid, such as the prong of a tuning-fork or the string of a violin. The sound from a wireless set is

usually caused by the vibration of a loudspeaker diaphragm, and it is only because these sounds are approximately of the same nature and frequency as those which are made in the studio by the vibration of strings, columns of air in the wind instruments, or the vocal chords of a speaker, that you appear to be hearing the actual sounds. These might equally well be reproduced by a gramophone, and, in fact, an appreciable part of the programmes—especially in the Empire broadcasts, which have to be made at night—are made up of recordings. The sounds are just as " real " as if they had not been " stored " on a gramophone disc or the Blattnerphone tape for a few hours. It is a matter of time alone.

The Blattnerphone is an interesting recording machine which now plays an important part in broadcasts. It enables sounds to be " bottled " for an indefinite period of time, and has advantages over ordinary gramophone records in that much less space is required to store a given amount of sound. The recording is continuous, does not have to be broken off at the end of a disc, and the reproduction is rather more life-like. The disadvantage, from the point of view of the ordinary user, is the great expense of the recording instrument and the special steel tape which is used. Because of this, it is not likely to take the place of the ordinary gramophone in the home for some time, in spite of the convenience of continuous reproduction.

The Blattnerphone stores sound by recording the sound vibrations in terms of magnetism. The

sound waves are turned into variations of an electric current, just as for broadcasting, but instead of the current going to a broadcasting transmitter it passes to a magnet. Naturally, the power of the electro-magnet at any given moment depends upon the current passing through its coils. A special steel tape travels past the magnet at constant speed, and the variations of magnetism are "soaked," or re-corded, in this steel. The tape is wound up and put away until wanted, when it is passed through the reproducing machine. This time, variations of magnetism are turned into variations of an electric current on exactly the same principle as a dynamo with its magnets inducing currents in wires. These currents can be amplified and carried to loudspeakers or fed direct to the transmitter. All forms of record-ing are very similar in principle and are closely related to broadcasting. In the case of broadcasting, the electrical variations are sent out as æther waves. These are caught by the aerial of your wireless set, "detected," amplified, and turned back into varia-tions of an electric current by a valve circuit, after which, with further amplification, they pass to the loudspeaker.

The reproduction could be carried out equally effectively through wires such as are used for the telephone. In this case there would be no need for detection. The vibrations would simply be amplified and brought to the loudspeaker. This system has, indeed, many conveniences, and with more and more stations demanding "space" on the æther, it may

come into general use. The great advantage of broadcasting is that it enables communication to be held at great distances and over stretches of sea from moving objects. But most of us tune-in to the local station, and this could equally well be broadcast to us through the electric light wires. We should need a much simpler form of wireless set and would not be worried by "interference." Most of the improvements in wireless sets during recent years have been devoted to cutting out interference and in enabling stations broadcasting on very close wave-lengths to be separated effectively. Eventually we might require the æther for broadcasting light or power, and we shall then obtain our entertainment through wires. As far as amusement is concerned, wireless was not an invention of the greatest importance, for broadcasting could have been carried out, before the discovery of the "æther," by means of cheaper and more effective land lines.

To-day, gramophones are generally operated in conjunction with wireless receivers, the change over being made by the simple movement of a switch. The same amplifying circuit is used for gramophone and radio, but, of course, no detecting circuit is required in the former case.

In the "all-electric" gramophone the motor is electric instead of being clockwork. This motor is exactly like that used in vacuum cleaners and refrigerators, with the exception that an accurate governor device is necessary to ensure that the turntable moves at a constant speed. This speed is

important in all forms of reproduction. In the Blattnerphone, for example, the tape must be run through the reproducing machine at the same speed as that at which it was taken through the recorders. The gramophone turntable must revolve at the same speed as the recording turntable. When " Speed 68 " is written on a gramophone record, this means, in effect, that the music was recorded at 68 revolutions and should be reproduced at the same number. It has obviously nothing to do with any question of the music being played " fast " or " slow," for the effect of speeding up the turntable is to raise the " pitch " of the whole performance, while slowing down the turntable has the opposite result. This can easily be tested, although a difference of pitch due to two or three revolutions a minute might only be noticed by a musician. In reproducing talking films, the speed at which the film passes through the " sound gate " has to be regulated most carefully. In television, synchronization is even more important. Fortunately, as in the electric clock, we have an accurate and easy method of synchronization in the even variations of an alternating current supply.

Musicians often say that the best reproduction is obtained from one of the " old " gramophones by the use of mechanical or so-called acoustic recording, but the majority of machines to-day are electric. All recording is also electric, and the change has resulted in improvement, not only of reproduction, but also of the programmes. It is possible to take the microphone almost anywhere, and such things

as the noise made by animals at the Zoo or military tattoos have been recorded, a feat which would have been impossible in the days when the performer had to sing or speak into a large trumpet. Electric recording or reproduction has the advantage that corrections and additions can be made in the electrical part of the operating gear. Although the direct needle, in which the sound waves are in a wax disc and afterwards transferred to a harder material, is free from electrical distortion, inertia plays a serious part in causing inaccuracy.

It is for a similar reason that headphones afford such pleasant reproduction. Their moving parts are light and do not cause distortion so easily as the comparatively heavy loudspeaker, which may have difficulty in following the intricacies of the waves. Apart from the inconvenience given to others, wireless should never be used at unnecessarily high volume. If it must be very loud, rooms should be insulated by acoustic material capable of dealing with notes of any pitch likely to be experienced.

In the recording room, which is now very like a wireless studio, a number of microphones may be used. If singers are recording with a band, one microphone may be used for the singers and another for the band, with proper arrangements for reflection when required. Their positions are carefully determined and a test made, with the recording engineers listening-in. The recording machine itself is generally in a separate room, which is well-heated in order that the wax of the special recording disc shall be

of just the right consistency to be cut by the "needle."

When all is ready, the engineers signal by lamps to the studio to begin, and the wax disc begins to move round under the recording needle. The apparatus for turning the record is not connected with any other part of the recording machine, and it has been found that a falling weight gives the most accurate result. The weight is wound as in a grandfather clock, and turns the table at a constant number of revolutions a minute. The sound waves picked up by the microphones are turned into variations of an electric current and mixed. They can be controlled if necessary, one part being made a little louder or other effects "faded in." They are amplified, perhaps a million times, and pass to the recording machine where the electrical impulses become mechanical movement—again on a similar principle to the electric bell—and agitate the cutting needle imposed on the soft wax surface, cutting a spiral, with each tiny sound wave indented in its edge. The needle is preferably made of sapphire, as in some of the older gramophones. The wax records can be "played back," but this means they are spoiled. The wax discs are sent to the factory, where the process of manufacturing the actual record begins.

A negative is made from the wax disc by giving it a metallic coating and then placing it in an electroplating bath. The negative is called the "master," and it is from this that the "mother" is obtained,

again by electro-depositing. Negatives are obtained from this record, the number depending on the probable popularity of the record, and these are used for stamping the records we use. The material used for records is a trade secret, but consists of a mixture of waxes, shellac, and other ingredients. This is rolled into a thin sheet and, while hot, stamped in a press at approximately 70 tons per square inch, the upper and lower portions of the press each containing a die. The record is cooled in the press, so that when it emerges it is only necessary to clean up the edges and label it ready for your gramophone.

The various ways which we have for "bottling sound" enable us to hear the great voices of the past and to preserve accounts of current events for the future. The British Museum has a large collection of master records which will be of great interest to future generations, while we are able to hear the voices of people long dead, such as Florence Nightingale. The little wave-marks on the record are the mechanical representation of sound waves, and while sound waves quickly expend all their energy, these mechanical grooves can be preserved for ever.

It is the great factor of time that governs all inventions; just as it defines the difference between gramophones, and radio which travels at the speed of light so that a man in Australia may hear a talk from London before it is heard by those who can actually see the speaker from the back of a large hall. The case is similar to that of transmitting

photographs and true television; for another instrument in which the need for speed has produced a new technique is the televista machine, which enables pictures to be broadcast to the home. At present the detail of views which are obtained is not very great, neither is it possible to magnify them without considerable difficulty. But the time will come when television will be as simple as any other form of communication and when the need to appeal to our senses will be met by this method. It is of vital importance to civilization that scenes as well as sounds should be made familiar to many, irrespective of the distance at which they may occur, and above all, simultaneously, or virtually so, with their production.

To take photographs or cinematograph pictures and to display them within a few minutes of their recording is interesting, but this transmission of pictures is not television in the fullest meaning of the word, however simple may be the process. Some find it difficult to understand how a picture can be sent across the æther, but in practice it is comparatively easy. Television is based upon an optical illusion; the picture is not transmitted, it is broken up into a number of little dots like those in a half-tone photograph, and each dot is turned into an electric current of which the strength depends upon the particular shading of the actual dot.

The easiest way to imagine the transmission of a picture by television is to take one spot on a picture, it might be the pupil of a man's eye or a tiny black

dot from a hat he is wearing. Through this dot a beam of light is passed, if a negative is being transmitted, or a bright light is shown upon the actual picture in the case of an actor. The next process is for the light from this same dot to be reflected into a photo-electric cell which has the property of producing minute currents in direct relation to the amount of light falling upon its sensitive surface. The current produced by the cell is then used to modulate or control the wireless signal, just as a microphone controls the wireless wave in the case of sound transmission.

At the receiving end the wireless signal is picked up, amplified, and caused to work a minute lamp, open a small shutter to pass a beam of light, or to activate a cathode tube. In every case the result is a spot of light corresponding in depth to the original spot transmitted. If now a " scanner " or moving mirror is used to direct the received spot of light to the same point of the screen and at the same time as the spot of light rests on the picture being transmitted, the two pictures sent or received will be the same as far as that one little spot is concerned.

Now remember that the human eye has the property of retentivity. A picture or light does not die away immediately from our senses. So if a machine is used which sends in succession little spots of light from all over the picture, these can in turn be thrown upon a screen to give the effect of a complete view. That is all television accomplishes. It turns the light from each part of a view into an equivalent

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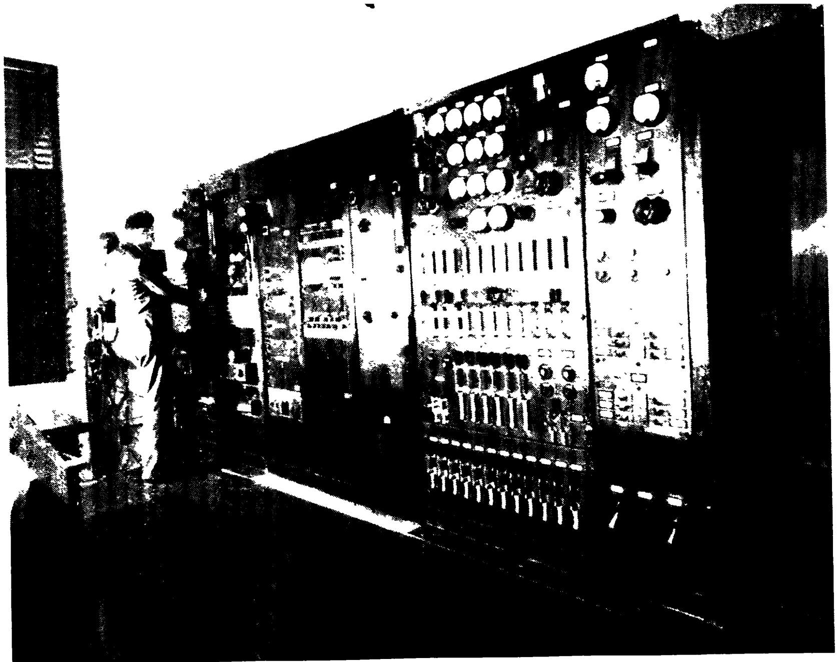

[Photo: Keystone-Underwood.

CONTROL PANEL IN A TELEVISION TRANSMITTING STATION.

value of electricity, controls a wireless wave in turn, and then produces at the receiving end the same aspect of light as was upon the original scene.

It is easy to understand that this mechanical process of imitation vision is difficult owing to mechanical difficulties, so electricians have applied a device called a cathode tube. This resembles a glass flask, and at one end is an oxide-coated filament forming the cathode, which—when made hot by the passage of an electric current, as in the case of a valve—disturbs electrodes which fly off towards the end of the flask. When these electrons strike a florescent material they produce a bright spot. Along the path of this "hose," as it were, of electrons are electrified plates which can deflect the cathode rays so that the ray can be pointed to any part of the base of the tube, and thus be made to correspond with the point on the original picture from which the rays are taking their instructions in regard to pattern.

It is probably no more than a matter of time before pictures, in colour and form resembling the original in every detail, will be transmitted over long distances. Television, originally conceived many years ago, is undoubtedly destined to prove a vitally important part of our daily life and to prevent the unfortunate need for bodily translation which at present wastes so much of our valuable energy.

The photo-electric cell is, literally, an electric eye. It has the property of being sensitive to light, and is usually made by coating a surface, inside a vacuum tube, by a metal of the cæsium type. The

minute currents which it sets moving when a light is shone upon it can be amplified by means of valves and made to perform many useful services. Doors can be opened by using a cell from which a current is taken to magnets arranged to hold the door in a shut position and permitting the light shining on the cell to be interrupted by people who approach the door so as to cross the path of the beam.

Eggs can be counted, smoking chimneys detected, or loudspeakers worked, as in the case of the "talkies." Talking films may one day be adapted for home use or for gramophones either with or without the accompanying pictures, for they are exceedingly simple when used with the photo-electric cell.

A film is made by taking the amplified currents from a microphone to a special lamp. The lamp marks on a film in lines of light and shade in accordance with the amount of current passing through the bulb. When this film is run between another light the transmitted beam varies in strength because of the dark or light patches on the film or on account of their size. If this beam is then directed on to a light sensitive coil the current given by the cell will vary in the same way as the currents taken from the original microphone, and can, in consequence, be used to operate a loudspeaker at the same time as pictures on another part of the same film are being projected.

The problems of wireless transmission are similar to those of reception, but on a larger scale,

for most of the energy of broadcasting is lost, and that which is picked up is very small indeed until it is amplified by the local valves with their batteries. Imagine a boy throwing stones into a pond very quickly so that ripples travel across its surface. If you were to put your finger into each ripple you could superimpose a certain shape, depending upon the size of your finger, upon the main wave of the ripple.

In radio broadcasting the æther is "jerked" into ripples by impulses from a valve system, and upon these carrier wave ripples the music is imprinted by currents from the microphone into which the music is directed. A microphone is rather like a loudspeaker used the wrong way round. Sounds enter the speaker, move the waves in front of other magnetic influences produced by coils, like the bell again, and so set up currents corresponding to the impulses of air caused by the sounds.

Radio is like a vast spring of which one end is vibrating while the other moves in unison. The earth is the storehouse of " spring " energy pumping its ripples into the æther for us to detect and amplify in ways which represent no more than the beginning of an electrical system that is hardly understood by human beings. It has been said the secrets of electricity and life will eventually be unravelled together. It is certainly true that, at the present rate of progress, radio will be technically unrecognizable within the next century.

CHAPTER IX

WHAT HAPPENS IN THE DUSTBIN

Rubbish is often defined as something worthless which ought to be thrown away, but it would be much more accurate to state that rubbish is something in the wrong place. An extraordinary amount of effort and ingenuity has been exercised during recent years to bring various kinds of "rubbish" into its right place. In any great industry there must be waste products, but every effort is made to turn them into by-products—something that is really useful. In the manufacture of coal gas we have come to the extraordinary position that the impurities, or by-products which used to be considered a nuisance, are now at least as important as the gas itself.

Every house has its dustbin, and into this bin goes every year material worth perhaps several pounds. Just think for a moment what you throw away. First of all, each day dust and cinders are emptied. What possible use can that be, you ask, and are glad to pay the dustman, through your rates, to carry it away. But dust or cinders are capable of producing heat, and heat means energy. The trouble is that you cannot utilize it yourself; if you have a dust destructor, it probably burns away the rubbish, and

wastes the heat produced. So you throw away your dust and cinders. Then every week you add waste-paper, old tins, perhaps rags, and various miscellaneous odd things, which are really what you call them—rubbish.

But see what that rubbish is worth. In Birmingham they are not content to collect rubbish and dump it into great destructors, or worse still, as in some towns, pile it into slowly smouldering heaps that become a paradise for rats. Not long ago the Salvage Department took stock of what it had collected in nine months, and amongst others things they found 4 ounces of gold (this, we can assume, was thrown away accidentally), 170 ounces of silver, 1½ tons of copper, a ton of lead, over 2 tons of aluminium, 350 lb. of pewter, and 2 tons of spelter. With other things, these were sold for over £2,000, a great deal of money to throw into a dustbin.

Obviously it is not worth while for the ordinary house to attempt to utilize its rubbish. The collection of metals at Birmingham was made from thousands of dustbins, and every man could not set himself up as a dealer in old metals. In a small way, people are being encouraged to burn their rubbish, where possible, in their house boilers. This effects a two-fold saving: it saves the cost of dust collecting, for there is less to collect, and it gives a little more heat to the fire. Some people save their newspapers, old iron, and rags, to sell to the men who call periodically, but most of us find that the price paid is hardly worth the trouble of storage. It is corporations that

are favourably placed, if not to make fortunes out of their ratepayers' rubbish, at least to recoup themselves for much of the cost of collection.

In place of the old dust destructors, progressive towns are creating "salvage departments." The rubbish, brought by many carts and lorries from thousands of homes, is emptied on to a moving band which passes over a draught fan which first removes all the loose dust. This is carried by large pipes to containers, and may be used in road construction or to fill up hollows in fields. Next, the moving band takes the rubbish past a powerful electro-magnet, which attracts most of the metal and sends it to a separate department where it is sorted. There are surprising finds amongst the metal—articles accidentally thrown away; and many people must be grateful for a scientific method of salvage, for under the common system of burning everything, their medals, pieces of jewellery, or whatever they may be, would have been melted down with the old iron or cinders.

The rubbish, which has lost its metal and its fine dust, is then picked over as it passes for various things. Paper, rags, old gramophone records, and many other articles commonly found in household rubbish can all be turned once more to good account. The utilization of these articles is hardly the work of a city corporation, so they are regularly sold to specialist dealers. The sums raised every year by these sales varies in the case of different cities from £3,000 or £4,000 to £60,000—enough to pay the

interest on the loan required for a new town hall or a block of flats.

Salvage can be carried too far. For example, an oil could be made from orange skins, but it has not been found profitable to retrieve them from household rubbish. It would probably be cheaper to use fresh oranges. There are many instances of liquid "rubbish," however, being allowed to ferment and thus to produce gas for heating.

After everything saleable has been removed from the rubbish, it passes to a destructor, where the combustible material is generally sufficient to burn by itself and to make a valuable amount of steam in the process. This steam may provide enough power for a large electricity works. In one town the electricity made by the burning rubbish is used to charge the accumulators that work the dust carts which do the collection. Even when rubbish has been consumed its value is not altogether lost, for the slag that remains can be made into "crazy-paving" stones. Alternatively, if clinker is made, it is sifted, mixed with other substances, and turned out as stones which will withstand heavy traffic. The contents of your dustbin, and sometimes sewage too, are often completely used in the course of a month. All that you called rubbish is turned into money, and things which you throw away to-day may turn up in a few weeks as part of a silver vase, a rivet in an Atlantic liner, a suit of clothes, or a paving slab.

One of the first laws of chemistry is that matter,

like energy, can neither be created nor destroyed. We used to take that for granted, and although occasionally disputed, from the ordinary standpoint, it is still, happily, true. Nowhere is it better shown than in the disposal of refuse. All the matter thrown into a dustbin remains matter and turns up again. And you put into your dustbin not only countless millions of atoms of useful elements but also hundreds of horse-power of potential energy. This is utilized in the destructor when steam is produced to generate electricity.

That is broadly what happens to your rubbish after it has been collected by the dustman. The exact procedure varies, of course, in different localities. In some small townships the amount of rubbish is not sufficiently large to justify such scientific disposal, but in time we shall give up, no doubt, the unhygienic habit of "dumping" rubbish, and perhaps organize its collection on a very large scale, with gigantic salvage plants dealing with the refuse of a hundred square miles.

What happens to the paper and the rags after they have been sorted out of the refuse? Paper is largely wood-pulp, and can be pulped again. It is not possible to make the finest paper from pulp produced from old papers. The removal of the printer's ink, which is carbon and impervious to bleaching, is one problem. But for such things as paper bags and cheap writing paper this pulp is quite suitable. All the old telephone directories in Britain are utilized for pulping, and when it is

realized that about 4,500 tons of directories are issued every year, it is easy to appreciate that the saving is considerable, especially as Britain has to import nearly all her paper pulp.

Rags are among the most valuable things found in rubbish. They are utilized in various ways, and the suit you are wearing at the moment may owe much to the rags collected from dustbins some time ago. A huge trade is done in "shoddy," which is rather an unfortunate name, for the cloth is by no means shoddy. Suitable rags are first chemically cleaned and disinfected, after which they are torn to rags by machinery. The value of these rags varies with the quality, but a fine Saville Row suit may, even after it has been ruthlessly shredded by these machines, be worth two shillings a pound, which is not much less than the price of some wool. The woollen fabrics are then rewoven by special processes into new cloth; this industry has now a capital running into hundreds of millions. It may often need an expert to tell the difference between the best "shoddy" and ordinary cloth woven from raw wool. More than one fortune has been made in Yorkshire out of shoddy, and the town of Dewsbury, where thousands of men are employed in the trade, is famous the world over for this enterprise.

Cotton rags are often used in making good paper, and linen rags may eventually become banknotes. It is said that old dress shirts are the foundation of much of the world's paper money. Cotton rags can also be employed in the manufacture of

artificial silk; and old silk stockings themselves, though they may appear little more than a collection of holes to their owner and fit only for where they go, the dustbin, have their strands separated for reweaving into new stockings.

There is no kind of rag which is useless. Even a battered old felt hat, which might be refused at the door by a tramp if you offered it to him, can be chemically and mechanically treated so that the felt appears again in a new hat. The coarser rags are utilized in the manufacture of roofing felt or similar materials, and sacks worn beyond use are turned into brown paper. If you look very carefully at a sheet of heavy brown paper you can often recognize the strands of material that once did duty in a sack.

Bones are generally classed with rags, and they are used in several ways. From bones can be made gelatine, which is valuable for many things—from certain sweets to jellies. Of course, the bones are first very carefully treated to remove impurities, and the gelatine industry does not rely upon bones from your dustbin. The gelatine which holds the sensitive chemicals on films or plates for a snapshot probably came from "old" bones. Even after the gelatine has been removed, these bones contain phosphorus in a form that makes it a good fertilizer. Most gardeners use a "bone meal," which is very good all-round for the earth.

Probably there are not so many men making a living out of collecting rags and bones to-day as there

used to be, but in France, where picking over dustbins is quite a profession, it is calculated that about £12,000,000 a year is made in the trade. The scientific method by which the rubbish is sorted under proper conditions is, of course, greatly preferable for hygienic reasons to the haphazard turning over of dustbins.

Apart from ordinary household rubbish, every trade and business has its particular kind of scrap. Almost as many fortunes are made out of using this rubbish as from manufacturing by " raw " materials. An amazing example of the value which " rubbish " may have is the case of pitchblende. This ore—which is found, among other places, in Cornwall—contains certain rare metals, and when these were extracted the residue was always thrown aside. It was not until years later that radium was discovered, and that pitchblende was known to be a good source. Meanwhile, thousands of pounds worth of radium had been thrown away as rubbish, and it is said that part of East London was built on this waste which was used to fill up a hollow. The ground on which such houses stand must to-day be worth many tens of thousands of pounds.

The more industry is studied the more one is amazed how little is wasted. Who would think, for instance, that a use could be found for dead flies. It would not be worth while to collect them from the window pane, but a regular trade is done at about 3d. a pound for chicken feed. Old motor tyres are cut up into lengths to make crude shoes,

mats, " fenders " for small boats, or even anchor for oysters where they are " farmed."

A fortune awaits any man who can find a us(something that is at present wasted in indu: At one time the residue left in making sugar considered useless. Now molasses is in great mand for the manufacture of alcohol, and aceto1 a substance which came into demand with creation of the artificial silk industry. Even gaseous waste of a chemical process may be valu Carbon dioxide is evolved in large quantities ir manufacture of a number of things. It used t lost—allowed to go up chimneys and mix witl air. Now it is solidified and is a valuable refrige Sawdust would seem a most worthless subst: except for packing and keeping rabbits. But n way has been found of converting it into sug alcohol by altering its atomic construction as i1 case of oil with coal, and a large plant erect(Russia uses all the sawdust that it can collect.

There is much that we throw away as rul that cannot be recovered. Few of us realize how much we waste in this way. It is said mustard manufacturers make their money, not the mustard that is eaten, but from the mu that is wasted. The same may be true of salt. have you ever thought that you waste more in your matches than you use. The average cig smoker probably throws away a good-sized t1 the form of half-burned matches. A leak washer may waste fifty gallons of water a day

Facing page 120.

[*Fox Photo.*

A DUMP FOR MOTOR CARS.
(On the Ealing Road near Alperton.)

mats, " fenders " for small boats, or even anchorages for oysters where they are " farmed."

A fortune awaits any man who can find a use for something that is at present wasted in industry. At one time the residue left in making sugar was considered useless. Now molasses is in great demand for the manufacture of alcohol, and acetone—a substance which came into demand with the creation of the artificial silk industry. Even the gaseous waste of a chemical process may be valuable. Carbon dioxide is evolved in large quantities in the manufacture of a number of things. It used to be lost—allowed to go up chimneys and mix with the air. Now it is solidified and is a valuable refrigerant. Sawdust would seem a most worthless substance, except for packing and keeping rabbits. But now a way has been found of converting it into sugar or alcohol by altering its atomic construction as in the case of oil with coal, and a large plant erected in Russia uses all the sawdust that it can collect.

There is much that we throw away as rubbish that cannot be recovered. Few of us realize quite how much we waste in this way. It is said that mustard manufacturers make their money, not from the mustard that is eaten, but from the mustard that is wasted. The same may be true of salt. And have you ever thought that you waste more wood in your matches than you use. The average cigarette smoker probably throws away a good-sized tree in the form of half-burned matches. A leaky tap washer may waste fifty gallons of water a day ; no

[Fox Photo.

A DUMP FOR MOTOR CARS.
(On the Ealing Road near Alperton.)

wonder some water companies will repair them free. If some one could find a use for old tea leaves he would certainly have plenty of raw material with which to make a beginning. The problem should not be so difficult, for the leaves contain tannin, a valuable chemical which is now a standard treatment for burns. Cold tea is well known to be good for burns.

The rubbish industry may one day be as big as the world of steel. It costs a million pounds a year to collect and dispose of London's rubbish alone, so that the problem is extensive. It is estimated that if all the rubbish in Britain, collected from domestic dustbins, was turned into electricity, over a thousand million units of electricity in one year would be produced. Even at a penny a unit this would go some way towards paying for the cost of collection. It is by no means an impossible dream. Many millions of units of electricity a year are already being produced, and the day may come when we will look upon our rubbish as our most valuable source of power. Waste is not confined to household substances. We waste energy by needless noise and in countless ways that will not be permitted in the future.

CHAPTER X

HOW THE HOUSE IS WARMED AND VENTILATED

In these days we all know the advantages of fresh air, and have learned to sleep with our windows open. But from the way that ill-designed windows are opened and shut it is obvious that many people still do not understand how a room is ventilated. Two things are called for, a place for the fresh air to come in and space for the stale air to escape. Although it is always the window we open when we want to let in some fresh air, we are apt to forget that the chimney has a very important function in letting out the " used up " atmosphere.

In the case of an electric fire for heating no chimney is required for the escape of smoke and gases, but houses will continue to be built with chimneys for the purposes of ventilation. Where there are no chimneys, some special arrangement has to be made for the introduction of air. When air is heated, as it is when it is breathed, it expands, so that a cubic foot of hot air weighs less than a cubic foot of cool air. This means that the hot air rises. So does hot spent air, even if at normal temperature it was heavier for the gases it contained. If, therefore, you wish to have a room well ventilated, you

should have the window open at the bottom as well as at the top. All the hot air, stale smoke, and gases will escape through the top, and the fresh air will come in by the bottom of the window. A certain amount of fresh air also seeps in by the door, and, in fact, in the normal house, the air is always circulating. The front door is opened and the fresh air blowing in takes the place of the stale air which rises to the top of the house.

Air consists, roughly, of 21 per cent. oxygen, 79 per cent. nitrogen, and .04 per cent. carbon dioxide. Although the carbon dioxide is present in such small quantities it plays a very important part, for it regulates the rate of our breathing. This is easily tested by breathing into a paper bag next time you suffer from hiccoughs. It is a most effective and scientific cure, for you will gradually breathe air containing an increasing quantity of carbon dioxide and this will soon regulate the trouble. Actually, when a man has stopped breathing he is not always given oxygen to make him breathe again, but carbon dioxide. The air we breathe out contains much more carbon dioxide than the air we breathe in, and it is for this reason that a room requires ventilation. If no fresh air were introduced, the oxygen would gradually be absorbed, and the percentage of carbon dioxide would rise until it would be impossible to sustain life.

Breathing is only one form of burning; our bodies burn oxygen. A flame will not burn in air which contains 2.5 per cent. of carbon dioxide and only 18.5 per cent. of oxygen. This fact has been

taken advantage of in certain fire extinguishers, which do not spray water upon the flames but smother them in carbon dioxide. The carbon dioxide acid is generated inside the fire extinguisher, after it has been closed, by the action of sulphuric acid on sodium carbonate, and it is stored under pressure until released by manipulation of the extinguisher. It is very possible that you have one of these fire extinguishers in the house or on your motor car.

Clearing away the carbon dioxide is not the only function of ventilation. When a room is " stuffy," this is often due to the warmth or stale smoke as much as to the actual increase in the percentage of carbon dioxide. Again, various gases are produced by the combustion of coal in a grate, and if you sit right over the fire the probability is that they, together with the excessive warmth, will make you sleepy. It has also to be remembered that the body does not only breathe through the mouth or nose. There is a true story of a girl dancer who painted herself all over with " gold," and then died, because her body could not breathe. It has been found that a man who kept his body in a room full of " stale " air, but put his head into a room of fresh air, still felt the stuffiness of the actual atmosphere. Fresh air contains many rare gases in minute quantities which are valuable although they seem to be of little use to the lungs. Stale air contains carbon monoxide under certain conditions—a gas with a serious and cumulative poisoning effect.

Much depends upon the correct temperature and

humidity of a room. It has been found that the average person feels chilly as soon as the temperature falls below 64 degrees. These figures are affected by the amount of clothing worn, but this temperature refers to an average person sitting still in a room. Neither does this cover every circumstance, for our sensations depend upon the "relative humidity" of the air, that is to say, the amount of water vapour which the air holds as compared with the maximum amount which it could hold at the given temperature. People in the tropics may feel it to be unbearably hot when the thermometer registers 90 degrees, whereas in England we might find this heat at least tolerable. The explanation is that tropical heat is often accompanied by great humidity. In England, on a keen frosty day when the air is dry, we do not feel so cold as on a day when it is moist. In both instances the thermometer registers the same degree of cold or heat, it is merely a question of what we feel.

An increasing number of householders are keeping a thermometer in their rooms, but, in practice, it is scarcely enough. A thermometer is useful in a living room because the human body makes such a poor measurer of temperatures, but this instrument should be accompanied by another which registers the relative humidity. It was customary to put a bowl of water before a gas fire, many people believing that it "absorbed the fumes." Even if there were any free fumes, which is doubtful, in all probability they would not be dissolved in this way. What may

happen is that the water evaporates and makes up for the moisture carried off by the hot waste gases from the fire. But there is little more reason why there should be a bowl of water in front of a gas fire any more than in the case of coal or electricity.

Many people have a terror of draughts, and although this can amount to a mania, it is certainly one factor to be considered in ventilation. Clothes dry more quickly on a windy day than when it is only hot. This is because the wind carries off the moisture more rapidly. But rapid evaporation has an effect upon temperature. The temperature is always lowered. What happens when you sit in a draught is that the slight current of air evaporates the thin film of perspiration, always present on your clothes, rather rapidly, and lowers the temperature of the skin. It is in this way that a chill can be caught. If you should have the misfortune to fall into a pond, there is little danger in getting wet. The risk lies in the rapid evaporation of the damp from your skin afterwards. For this reason also clothes should always be changed immediately after any free perspiration. More chills are probably caught during rest after a game of tennis or a round of golf, without changing, than from any door being left open.

The normal flow of air in a room is generally from the door upwards to the ceiling; the air finally escaping through the top of the window. There is also a flow of air up the chimney. The flow of air in a room is easily examined by holding a smouldering

piece of brown paper in various positions. Obviously, in a well-designed house, care is taken not to place the fireplace directly between the door and window, or there may always be smoke blowing into the room.

The problems of ventilating and heating are therefore intimately connected, and it is now realized that they are of great importance to health. Tests have shown that the efficiency of the body or mind varies with temperature, and there is an ideal temperature, with correct relative humidity, at which body and mind are at their best. This ideal is about 69 degrees. If the temperature falls substantially, efficiency is impaired. In the usual method of heating by a fire, with ventilation by window and chimney, it is very difficult to maintain a constant temperature. One of the disadvantages of the coal fire is the uneven temperature produced. It blazes one moment and dies down the next. Moreover, one part of the room is very much warmer than another.

To overcome these disadvantages a system of heating and ventiliation called " air conditioning " has been invented. It is to be found in few private houses as yet, but it is now widely used in large blocks of offices, in cinemas, factories, and big ships. In time, no doubt, houses will have fresh air and warmth laid on in much the same way as they now have electricity or water. A fresh-air service is certainly as essential to happiness and comfort as either of these other two normal supplies.

Air conditioning amounts to choosing your own weather in the house. The principle is simple.

Before being introduced to rooms, the air is cleaned and heated or cooled. Water vapour is added or removed as required to bring it to the correct relative humidity. When we open the window to let in fresh air we also let in the fog, cold, and possibly rain. Moreover, there is no way of controlling the amount of moisture in the outer air.

In air conditioning the air is first filtered to remove all soot and other impurities. The amount removed in a city like London is surprising, and it is rather terrible to think that usually we breathe in all this dirt with our oxygen. The air is sucked into the system, usually on the roof by a fan, and driven along large pipes. After cleaning, it is warmed or cooled to the required temperature, water vapour is added or removed, and it is then passed into the room at floor level. In cinemas the air inlets are neatly concealed and silenced, but in any case a grid much smaller than the average central heating radiator is required. The stale air is sucked away at the ceiling.

This machinery may sound complicated, but the work is almost entirely automatic. By using thermostats the temperature is automatically controlled. A thermostat is a special kind of thermometer in which, when the temperature rises above or falls below a certain point, the fact can be registered, and a device put into action which in turn controls the plant. If the temperature falls below the required mark, the heating plant automatically works a little harder, and the temperature goes up as the

warmer air is introduced. When it reaches the maximum level the heating is eased off.

The vastly improved atmosphere inside the modern cinema is due entirely to air conditioning. In London, in fact, the air is often fresher inside a cinema than it is in the streets. Experiments have revealed that it is difficult, if not impossible, to take cold in an air-conditioned room. Some time ago a number of people with bad colds were put into an air-conditioned chamber with a number of others who had no colds. The temperature of the room was kept at 70 degrees, with a relative humidity of 55 per cent. These patients were left together for from five to eight days, but the colds were not transmitted. Cold germs are, perhaps, no less effective in air-conditioned rooms, but what is suggested is that by avoiding the "little chills" which we are almost bound to receive in normal rooms we offer the germs less opportunity to work.

Direct heating of the air in a room is the common-sense method of warming it, for fires and radiators of all kinds have this object in view. There are three ways in which heat can be conveyed from one body, such as a fire, to another, such as our hands. These are conduction, convection, and radiation. We depend very little for warmth upon conduction. When we place cold hands on a hot radiator, we warm them by conduction. Convection plays a very much more important part. The air in front of a fire is warmed, passes upwards when colder air takes its place, to be warmed in turn and passed on until the whole room

is warmed. A whole room is seldom properly heated by convection, for by the time the last air has been warmed the first air, perhaps, in a far corner, has cooled. We receive warmth by radiation from coal, gas, and electric fires. The glowing coals radiate heat, which passes directly in rays to our bodies. In the case of electric fires the filaments glow, and in the case of gas fires the glowing clay sends out the heat. Naked gas jets burning in a room would be a poor method of heating, for apart from the warmth they give, some radiations have a definite health value, and the treatment of certain illnesses is carried out in this fashion.

An increasing number of houses have central heating ; most have at least the bath water heated by a central fire. The arrangement is very simple, and depends upon the fact that water, like air, when heated becomes lighter and therefore rises. We have two main pipes running up the house, one carrying cold water down and another carrying hot water up from the boiler. The cold water enters the bottom of the boiler, is heated and rises, leaving it at the top. In the same way, in the hot-water storage tank, the cold pipe enters at the bottom and the hot leaves at the top. When we feel the tank to see if the water is hot, it may be found that this tank feels quite cold at the bottom but it is still hot at the top. Water is a very poor conductor of heat, although it carries heat quite well by convection. You can weight a piece of ice in a test tube of water, and boil the water at the top of the tube before the ice at the bottom will melt.

Wherever hot water is required it is merely a question of tapping the two pipes and taking in the cold water and drawing off the hot. Always the hot will enter at the top and the cold will be drawn off at the bottom.

The usual method of central heating in private houses is to distribute the heat by radiators. In public halls long pipes running all round may be used. Radiators may be camouflaged, but they usually have a corrugated surface in order to increase the area presented to the air; the greater the surface the greater is the amount of heat radiated, for cooling can only take place at the surface. The corrugated system is used to save space. Heating and cooling are one and the same process; when we speak of heating a room, we really mean cooling a radiator, or when we speak of cooling a radiator, as in a car, we mean heating the surrounding air.

Central heating is a convenient and, generally, very economical method of warming a house. The complaint that it means "stuffiness" is generally due to the radiators being run too hot. A temperature of 160 degrees in cold weather is sufficient. In milder weather a fall of 20 degrees can be permitted. These temperatures, under normal circumstances, will give the required air temperature of about 70 degrees. Only too often, however, the water in radiators is very near to boiling-point. A further disadvantage of allowing the temperature to rise too high, which is perhaps the true explanation of "stuffiness," is that particles of organic dust in

the air come into contact with the hot surface and produce a smell.

In trains central heating is usually carried out by sending steam through the pipes instead of water. This is more efficient, and although impracticable in most private houses, in America a steam heating plant is often laid down for a group of houses or flats. Steam can be transmitted farther that water without uneconomic loss, and in some cases it is sent for over a mile for heating purposes.

Radiators are generally heated from a central boiler, which, for the sake of economy and easy running, is fired by coke or anthracite. If ordinary coal were used, constant attention would be required, and the soot might block the flues more frequently. It is possible, however, to have individual radiators heated by gas or oil. In this case the radiators really become a special form of gas fire; the heat, instead of being transmitted directly to the room, being sent through the medium of water. In one form of stove a special stone is used which has great powers of absorbing heat, and continues to warm a room many hours after the heat has been turned off.

The heating and ventilating of our homes is a subject of considerable importance which does not receive the attention that it deserves. Once it is realized that hot air or hot water rise and cold air or cold water sink, it is entirely a question of common sense that our homes should be comfortable.

Upon this very simple fact depends much of our health and happiness. Proper heating could be

built into houses at a cost little higher than that of the usual refrigerator and radiogram. Combined with a small coal fire in the most-used room it is a blessing too long delayed in modern architecture.

Houses of the future must be effectively heated. Should electrical energy become available for this purpose at reasonable charges it would be possible to store heat at the period of load when electric units are cheapest, and to use them to warm a house at a time when central station demands are at a maximum. To provide hot water for washing purposes from part of the same system is a simple matter that could add much to the peace of everyday existence.

CHAPTER XI

HOW WE GET OUR WATER

It is not until we experience a country camp that we realize how much water is needed every day. For drinking only a few glasses, two or three pints. A gallon or two for cooking, and some for washing-up, and, of course, there is the water for washing or bathing. When water has to be brought in buckets from a well a mile distant, there seems to be an endless demand, and yet it is safe to say that not more than half the quantity is used in comparison with a small home. Every man, woman, and child in this country uses about twenty-five gallons of water a day. Pure water, from being a luxury, has become so plentiful and cheap that few of us do not waste a great deal, either by washing with running water or by allowing leaky taps to remain unmended.

It was not always so. Even to-day, in many countries, water is comparatively scarce, and rarely very pure. The supply of naturally pure water is limited, and for most of our water we are dependent upon waterworks, where it is purified before being pumped along mains. We are apt to think of this supply as unlimited, and it is only during prolonged

droughts, when we are restricted in the use of water in our gardens or for washing cars, that we have a hint of the vast task involved in supplying a great city like London. Even then it is remarkable that the large cities are usually the last to suffer, and it is small villages depending upon wells or other natural water supplies that suffer most during dry periods.

Domestic water comes from many different sources, although it all originates as rain. In some cases this rain drains from the land into streams, and rivers are then tapped for drinking water. River water is generally very contaminated. It is natural that the water draining off the land in this way should be full both of suspended matter and of bacteria. Decaying vegetable and animal matter produce bacteria, which are all washed together into any river. Lakes are another source of water, and, like mountain streams, the water may be comparatively pure. Sometimes water is drawn from artesian wells. In this case the water has soaked through the ground, been held up by a layer of hard rock, and formed into underground pools. Artesian well water is generally clean, for the earth itself has acted as a filter, and the water has been cleansed while it seeps slowly through the strata. London is particularly rich in artesian springs. Under London's layer of clay is a layer of chalk seven hundred feet thick. This is capable of storing a tremendous amount of water drawn from rain that falls over a great area. With most underground water supplies the effect of a prolonged drought is seldom felt

immediately. It is not until later, when water which should have been seeping through is not there, that the wells run dry.

Well water is generally fairly pure because of the natural filtration it has had, but it is liable to contamination when exposed. It is for this reason that wells are so carefully lined to prevent water in the soil and rock higher up leaking in to join the deep water from the well. Rain water alone is now seldom used, although in many country houses it is still collected from the roof. Rain water in the country is very pure. It has been recently distilled, and is, therefore, tasteless and insipid for drinking. For the garden it is excellent. Tap water is generally cooler than the air and may chill plants, whereas the soft rain water is exactly the "drink" to which they are naturally accustomed.

Although the amount of rain that falls in any given year, or, for that matter, any given month, remains fairly constant in every district, it does not rain every day. Nor is the demand for water constant. During the night very little water is used, and in the day the demand may vary from hour to hour. For this reason water has to be stored. Most large cities have storage reservoirs holding enough water to keep them supplied for several months, although the position may be complicated by other factors. It might seem ridiculous that London should be short of water, even after a prolonged drought, with the river Thames flowing past. But, obviously, if more than a small proportion of

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[*Photo: Keystone-Underwood*

WATER SUPPLY FOR STOCKPORT.

(Part of the beautiful Goyt Valley in Derbyshire is being transformed into a reservoir. A section of the constructive work, showing the pipe line.)

the river water were diverted to waterworks there would be serious results, so that when the amount of water flowing over a weir falls below a certain level, the water company is restricted in its input.

Storage of water is important from quite another point of view. During storage most of the harmful germs die a natural death. After two weeks only a few stray germs are found. In one experiment nearly half a million typhoid germs were introduced into a cubic centimetre of water, which was tested every week. At the end of the second week only eleven of the half-million had survived, and after six weeks no germs at all were found in ten cubic centimetres. Storage may therefore be the first stage in the purification of water, and at London's huge reservoir at Staines, to take an instance, water is kept for about thirteen weeks. During storage certain undesirable plants may grow in the water, and for this reason very minute doses of chemicals may be introduced. The amount used is so small, perhaps one part in ten million, that even if it escaped the filter bed it would have no effect upon the health of human beings, while, on the other hand, it is fatal to the small algæ.

Reservoirs to-day are generally built of concrete and cement, but for very large capacities advantage is generally taken of an existing lake or hollow which may be enlarged by means of a dam. While the water is in the reservoir much of the sediment falls to the bottom. In the case of a deep reservoir this amount may be considerable and call for dredging.

The bottom can sometimes rise by a foot or more in a year owing to the settling of small particles.

Perhaps the most important part of the water-works is the sand filter. It is curious to think of small grains of sand acting as a filter, but for this work a bed of sand makes an ideal filter. The sand has various actions. From the chemical point of view it holds back any suspended matter that has not settled as sediment. It removes small vegetable or bacterial growths, and has further chemical effects. The water is distributed finely over the surface of the bed of sand and trickles through very slowly. The minute particles of extraneous matter cannot find their way through the openings between the millions of grains. They could work through a dozen minute cracks, but are soon lost and held up after many thousands of such passages. Most of the matter is caught in the first few inches of the sand, and if you have ever seen men cleaning up an "exhausted" filter bed you will have noticed that the top layer of sand is discoloured.

The chemical action of the sand is the result of oxidation. Any free ammonia is turned into a soluble compound, and organic matter is destroyed. Germs are killed by being held up in a thin slimy film that forms on the sand grains, and this thin film is often the most important part of the filter bed. Well water is generally fairly free of germs because the water, in seeping through the ground, has been treated naturally by the same process as we employ in artificial sand-filter beds.

It is curious but true that dirty sand filters better than clean sand, and in most waterworks the first water running through a new filter bed is allowed to go to waste. In some cases the water is discarded for twenty-four hours, in others for two weeks. The practice varies, as does the depth and treatment of the sand. In many waterworks, when the top layer of sand becomes exhausted, it is removed and the water then proceeds through the freshly exposed layer underneath. In this way the sand is all gradually removed, after which a fresh bed is made up. Underneath every sand filter is a layer of coarse clean gravel. The time for which a filter will work before it requires "paring" varies very greatly, from two or three days to several months.

The only disadvantage of the sand filter is that it is slow, and that to treat a large amount of water the filters must be of considerable size. Mechanical filters have been invented to make the process of filtration quicker, and these are necessary in cold countries where open water is frozen. It would be impractical to use sand filters taking up a great deal of space under cover. There are many mechanical filters, but in all of them the natural film formed in sand is replaced by an artificial film. Sulphate of alumina is also used to coagulate the sediment.

Water, of course, is not distributed after one simple filtration. It passes through several beds, and may be further treated with chemicals such as chlorine or ozone. From the waterworks, where it is periodically tested for chemical and bacterial con-

tent, it passes into "mains." These may be of iron, steel, or concrete, but the great object of engineers is to keep them absolutely watertight, not only so that there shall be no waste by leakage, but so that no impure water or sewage shall leak in. Sewage is the greatest enemy of a pure water supply, and it is through contamination by sewage that cholera epidemics have been set up. Fortunately, owing to the care with which our water is prepared, a cholera epidemic is unknown in Britain, but other countries are not so fortunate. Diseases due to water are now exceedingly rare in Britain, and for this we have to thank the scientists who keep a ceaseless watch on our behalf.

Although water is thoroughly purified at the waterworks it often comes to us very "hard." You may have noticed that in one part of the country soap gives an easy lather, whereas in another this process may take several minutes. "Hardness" is due to dissolved salts of calcium and magnesium which, with soaps, may form an insoluble compound. This is deposited as a scum on the basin, and no lather can be formed until all these hards salts have been thrown out of the solution. This "softens" the water, but it is both inconvenient and wasteful. In districts where the water is really hard, such as London, a big handful of soap flakes has to be thrown into water used for washing-up.

There are two kinds of hardness, known as temporary and permanent. Temporary hardness is removed by boiling. With temporary hardness,

carbon dioxide is given off when the water is boiled and normal carbonates are formed which are thrown out of solution. This is the familar " fur " that forms inside our kettles, slowly in most places, but very fast in districts where the water is hard. It also forms inside hot-water pipes if the water is allowed to get very hot. It is inevitable inside boilers, which have to be periodically " de-furred." The fur is wasteful, for it prevents heat reaching the water effectively, and after some time may close a pipe completely. It will not form so readily if the temperature in central-heating pipes is kept more moderate.

At the waterworks hardness may be removed by adding a carefully calculated amount of lime which throws out the offending salts ; but this is not always easy, as it is particularly desirable that there should be no lime left over in the water. Various automatic devices have been invented for distributing the right amount of softening chemical. The precipitated substance settles very slowly, and in order that the supply shall not be held up unduly it has to be filtered through a screen. Considering the trouble caused in boilers by temporary hardness, the cost of removing it at the waterworks, which may be a penny for every thousand gallons of water treated, seems well expended.

Some companies remove the hardness, but others do not, and filters are therefore introduced to an increasing number of private houses. These filters are not to purify, but merely to soften the water.

If water has to be purified a charcoal or porcelain filter is used, but these are rarely now necessary in England. In one ingenious system of water softening the water is made to trickle through a layer of sodium silicate. Calcium silicate is formed, which remains in the filter, while a soluble sodium carbonate passes on. After a time, of course, all the sodium silicate in the filter is exhausted. It is not necessary to replace this, however, for by passing a solution of salt through the filter the substance is "regenerated." What happens is that the salt acts with the calcium silicate to form sodium silicate once more, leaving calcium chloride, which is readily soluble in water, to be washed away.

CHAPTER XII

CARPETS AND LINOLEUM

CARPETS are one of the most ancient of all comforts. Even to the earliest nomadic tribes the ease with which they could be rolled up and carried must have made them especially useful. In the East carpets served not only as floor coverings but also as walls and shades. They were used almost as we use curtains, screens, or pictures. But the carpet as a part of the furnishing in an ordinary English house is a comparative innovation. It is obvious that while the " knotting " of a single carpet occupied a man for a year or more, the price remained far beyond that of the ordinary householder. Until the middle of the eighteenth century carpets were only for the rich. During that century occurred the greatest of all revolutions, the Industrial Revolution, and with it the introduction of power for industrial purposes. Among the other machines to which power was applied was the carpet loom. With machinery taking the place of fingers in making the " knots " of a carpet, it was possible to produce carpets at such a price that they were soon found in almost every house.

To many people " hand-made carpet " is a

description that has a certain attraction. They like to think of rugs being made in Oriental bazaars by a whole family sitting round a piece of canvas tying " knots," or weaving a pattern that has been traditional to them for generations. Allowing for a certain degree of charm in hand-made carpets from the Orient, much of the prejudice in their favour is based upon sheer ignorance of the facts. Very few of the rugs or carpets which so many people admire have ever been so near to Persia as to Yorkshire or the Midlands. Machines imitate Oriental carpets very skilfully, and while the preference of clear thinkers may be for a carpet of modern design, rather than one which is an imitation of an Oriental pattern, machine copies are almost undetectable. The genuine hand-made Oriental carpet is now comparatively rare and expensive, certainly beyond the means of most purchasers. Quite a number of hand-made rugs are glycerined and ironed to give the effect of age. Many buyers are impressed by the " old look " of an Oriental carpet, but they would do well to remember that this ageing may have taken place in a day with the help of modern science. They overlook the damage that chemical processes of this kind may cause to the fibres of the actual material.

Carpets as a branch of art are possibly rather more selfish than are all other forms of antique possessions, for their value seems solely to depend upon the number of people who do not own their beauty. The introduction of mass-production methods to

carpet making has been of immense benefit to the general public, as in virtually every other mechanical introduction.

There are many different kinds of carpet, at first distinguished chiefly by the places at which they were made ; but now the difference is in the method of making. Axminster carpets are no longer made at Axminster nor Brussels carpets in that city. Various materials are used for carpet making, from horsehair and jute to wool or silk ; the most important is, undoubtedly, wool. Before any material passes to the factories it is hygienically treated, and although carpets made in Durham or Dundee may lack some of the picturesque names or patterns of those from Eastern countries, we are well compensated by the knowledge that they have been clean at every stage of manufacture.

Dyeing plays a very important part in carpet making, and of this subject there is much misunderstanding. Most of the Eastern carpets are dyed with colours extracted from natural vegetables. The wool for factory-made carpets is dyed with aliarine and aniline dyes, which are synthetically prepared, chiefly from coal-tar chemicals. The reason why these synthetic dyes are used is not so much because they are cheaper, but because they are more certain. It is difficult to obtain exactly the same shade with each batch of vegetable dye, and it is much more reliable to use chemicals of known formula, when the strength can be calculated accurately.

The housewife who tries to match a piece of material to-day is often successful, because a definite chemical used at an exact strength in the same way always gives the same results. A hundred years ago matching a piece of material must have been a matter of luck, for a manufacturer could never be quite sure that one batch of dye would provide the same colour as the next, except in the case of black. To-day colour testing is not even carried out with the eye. Instruments are used that can measure æther vibrations—and colours are only different bands of the spectrum—far more accurately than the eye, so that precise names can be given to the almost infinite variety of shades of every colour.

The first carpets made in England were "Brussels" carpets, and are distinguished by having a pile made up of loops instead of single threads. A Brussels carpet is woven much like a piece of cloth, but in order to give "body" to the carpet, in addition to the usual warp threads there are "chains" and "stuffers." The chains are raised alternately and the shuttle shot through them. The stuffer does not rise and fall, but remains in the middle of the carpet base. The action of the loom is almost entirely automatic, being governed by the Jacquard machine. The carpet, after being woven, has to be measured, dried on heated rollers, sheared to remove the fine projecting pieces, and finally, perhaps, ironed to prevent the pile spreading or showing the "body" below, a defect which carpet dealers describe graphically as "grinning." All

or most of these processes are carried out by machinery.

If a carpet is to be made up from squares, it is sewn together by electric machines, this being carried out so carefully that the joins are only barely visible. Larger looms now make it possible to produce " seamless " carpets.

Wilton carpet is manufactured in much the same way as Brussels, and often the same looms are used, but with this type the loops are cut, giving a much softer surface. More wefts have to be used to hold down the pile effectively. Most Wilton carpets are plain and give the effect of showing footmarks when walked upon. This is called " shading," and is due to the pressing of some of the pile in one direction while the rest is pushed in another. The result is an unequal reflection of light, which appears to give a different shade.

Axminster carpets, which were introduced into England only about sixty years ago, are really the nearest to the hand-made carpet of the East, for they have " tufts." These are woven in instead of being knotted as with a hand-made carpet. The machines on which they are made are very wonderful pieces of mechanism. The " tufting carriages," with their correct colours, travel over the body of the carpet, and in spite of their complication are dropped into place at exactly the right moment, to be securely bound by the " chains." Although the mechanism is intricate, it is of a straightforward mechanical nature. It does not make use of the " invisible-eye "

or any other very modern invention, but relies upon the ingenious use of such standard mechanical devices as cams or levers to secure perfect timing. The " tufts " are not knotted, but are held by the warps just as securely as if they had been tied by hand.

Chenille carpets are made in two parts. The first consists of making a " fur " ; this is accomplished by weaving a cloth in accordance with a pattern and then cutting it into strips by means of knives. The weft threads are cut by the knife, forming a " fur " which is doubled over mechanically and securely held by a cotton weft. This fur is afterwards woven into a carpet in much the same way as with Brussels and Wilton. As in all carpets, instead of there being a single row of the warps and wefts seen in cloths, several are used to give thickness with strength. The Jacquard loom plays no part in making the design of this type of carpet. The pattern is decided in the first stage, when the fabric is woven in accordance with a predetermined design which has been cut up into strips like the cloth itself.

Tapestry carpets are made like Chenilles by two processes; they are more like Brussels and Wiltons in appearance. The tapestry carpet is the only one that is printed. The " printing press " is a large drum on which the yarn is wound. As the drum revolves it is brought up against a colour carriage at the required intervals. After all the yarn has been printed, the surplus colour is scraped off, the

yarn removed, and steamed to secure the colour. These lengths of yarn form the warp of the carpet; allowance is made for the fact that when they are woven up the length of any colour showing will be reduced by the amount taken up in loops; in other words, the yarns and the pattern are elongated. The yarn is woven in very much the same way as with Brussels carpet, but as the pattern has already been decided there is no need for a Jacquard.

The ingenuity invested in making these simple articles of furnishing is remarkable. A huge variety of colours and patterns is now available, and it is all the more extraordinary that if you go into a shop prepared to spend only three or four pounds on a carpet you can find a far better selection than could have been offered to a queen four hundred years ago. Queen Elizabeth is believed to have been the first person to use a carpet in a normal house. In those days strewn rushes were the universal floor covering, and they were usually less artistic and far more dirty than any carpet. To keep a room clean meant frequent renewal of the rushes, and even in the houses of the wealthy this was not possible every day.

Linoleum is also used as a floor covering in almost every house; it is difficult to realize that this material was a novelty to our grandmothers, and unknown to our great-grandmothers. Actually, it is not a hundred years since the first real linoleum was patented, although it was not even called linoleum and did not embody the essential processes used in the manufacture of linoleum to-day. Previ-

ous patents had been taken out for printing in oil-colours upon cloth, and the finished product was rather like what we now call oil-cloth, although the resemblance is not remarkable. A hundred years ago inventors were experimenting with the use of India-rubber and cork dust. Cork dust is still a very important ingredient of linoleum, but, for the most part, we have dispensed with the rubber.

The real inventor of linoleum was Frederick Walton, who also created the name which has now come into general use. He made this name by joining the Latin words for flax and oil—*linum* with *oleum*. These two substances were all-important to his linoleum in 1860, and they remain so to-day. Large quantities of linoleum are made in the city of Dundee because the people there have long been trained in the manufacture of jute, which is so extensively employed for the burlap or backing.

A number of other materials are used in making linoleum, of which the most important is linseed oil. The oil is expressed from the seeds and the first process consists of solidification. This is carried out in various ways, but in one of them manganese borate is added and heated with the oil, which is then subjected to mechanical treatment. This may last for days, and ends with the oil at the consistency of dough. In another process " drying " chemicals are added, and the oil is boiled while compressed air is pumped into its mass. There are other processes, but in every case the oil finishes as a thick substance called " linoleum cement."

Linoleum manufacture consists of incorporating with this cement a suitable filler, which may be ground cork, wood flour, or other suitable substance. The cement is first ground between rollers, and small quantities of materials such as resin or gums are added. This mixing with the filler is carried out mechanically. After this, the initial "rolls" are "scratched" to small granular pieces, and these are dealt with in accordance with the type of linoleum. If plain linoleum is required, colouring matter is incorporated and the granulated material is fixed to the backing of canvas by being pressed between rollers. With printed linoleum the same treatment is carried out, but the roll is afterwards partly baked and then printed with varnish paints. As the pattern in this instance is only on the surface of the material, it wears off more quickly than when it runs through the thickness of the composition to the canvas back.

In making inlaid linoleum the canvas backing is laid on a suitable table, and stencils representing the pattern are placed upon its surface. The granulated material is then sifted on to the canvas through the stencils. Each colour has its own stencil, and the pattern is built up of different colours in much the same way as with a three- or four-colour printing process. When all the openings in the stencil have been filled, the sheet is passed through an hydraulic press where the grains are consolidated. Like all linoleums the inlaid type goes through a "curing process" which may last for weeks.

Straight-line inlaid linoleums, usually of parquet or tile pattern, are made by cutting the pieces to the required shape from a roll of the granulated material and then applying them to the canvas backing as required. This work can now be done by a very ingenious machine which has knives so placed that it cuts out the required shapes and applies them by selective plungers, any waste pieces being carried away from the machine. The canvas may pass under as many as six of these machines, each one of which lays on certain pieces. Finally, the linoleum has to be consolidated, as with ordinary inlaid, and cured.

The discovery of plastics has had an effect upon linoleum, for the linseed oil is expensive. Nitrocellulose products are now being used with satisfactory results in some factories, either alone or mixed with linseed oil.

It is difficult to imagine a world without linoleum to-day, for the material is easily cleaned, and has a very hard-wearing surface. In the past fine floor surfaces of wood or inlaid stones were rare. The skill with which science has imitated them at a fraction of the cost was revealed when a domestic help saw a wood parquet floor for the first time and said, " Isn't it wonderful how they get the wood to look like lino."

CHAPTER XIII

BACK FROM THE LAUNDRY

On Monday we pack up a basket of dirty clothes and linen, give it to the man who calls with a van, to forget all about it until two or three days later, when it is returned, spotless and neatly ironed. Sometimes there may be grumbles about the bill, or because some article has been mislaid, but in general these jokes about laundries are no more true to life than those concerning Aberdeen. In recent years most women have resented the drudgery of the wash-tub and laundries have become more popular. The modern habit of living in flats has also stimulated business for laundries, and the time may well come when " doing the washing " at home, unless the house is large enough to justify the installation of an electric washing or ironing machine, will be as rare as destroying the contents of a private dustbin.

Laundering is a scientific business to-day, and the " washer-woman " with her elbows immersed in a tub of soapsuds has disappeared from all large laundries, where the work is done by machinery upon scientific lines. The various laundries contribute to the upkeep of a special laboratory, costing £15,000, in which research is carried out unceasingly.

The fact that the Government make a grant for this work demonstrates that the laundry is an affair of national importance. Keeping our clothes clean has, indeed, become a major industry; it is the fourth most popular trade for women in Britain.

The most common accusation against any laundry is that it shrinks garments. Shrinkage is a problem, but it has been tackled scientifically, and it is now known how to wash clothes without any trouble from this source. Neither is it always the fault of the launderer, for there are still manufacturers who do not carry out the necessary mechanical shrinkage upon their cloth. This was discovered in the laboratory, and has resulted in consultations with clothing producers. A shirt that comes back from the wash three inches too short is usually a very bad advertisement for its maker.

When once the basket of clothes is collected it joins hundreds, perhaps thousands, of similar baskets. The first task of the laundry is to check your list against the clothes, marking and sorting them into bundles. This has still to be carried out by hand because no apparatus has been devised for discovering the eccentricities of the housewife who marks down seven sheets when she has only forwarded six. The sorting is carried out according to the fabric of which the clothes are made and the treatment they are to receive. Socks, for instance, go to one section and handkerchiefs to another. In all there are probably two dozen different classes of clothes for treatment.

The various bundles go to the washing-house, where they are placed in large metal drums. In place of the kneading by the washerwoman's hands, rubbing against a corrugated board, or even smacking of the cloth on a flat stone, like an Indian dhobi, we have the systematic percolation by water containing carefully chosen soap.

The process may be longer, it is seldom shorter, than in the home wash. For example, a white shirt may be in the washing machine for over an hour, but, of course, it is quicker in the end, because there are dozens of shirts in the same drum. The thorough "percolation" of every garment is ensured by the mechanical revolution of the drum. This is not a regular turning, but an eccentric movement, and it may be aided by beaters within the drum moving gently but firmly to squeeze soapy water into the cloth so that each fibre is contacted with the liquid.

Treatment varies with the material. It is unwise to rub flannel, and the machines that deal with flannel garments are restricted to a firm but gentle kneading movement. The temperature of water in the washing machines is not constant, but rises gradually, and rinsing can be carried out by passing in clean water. Rinsing is, of course, just as important as washing, for to extract dirt into the water and to allow it to dry in the clothes is a mere waste of effort.

Instead of being passed to a wringer to squeeze out surplus water, the clothes pass to an extracting machine. In this centrifugal force is used, and the

water is thrown out by a whirling action. The "hydro-extractor" is a hollow cylinder which can be revolved at over 1,000 revolutions a minute, and this gets rid of water very quickly. The articles are still by no means dry, and the exact methods of drying depend very much upon the nature of the clothes. Socks may be dried upon special metal feet so that they keep their shape, and a pair of curtains would be dried together to prevent any variations in length or breadth when finished. Most articles are dried by attaching them to a "clothes line" which moves continually through chambers containing hot, dry air. To rely upon the sun for drying or bleaching would be impossible in commercial work. There may be some magic about sun-dried garments, but scientifically it can be duplicated with ease and with much greater certainty.

Again, in the case of ironing, the device used depends upon the garment. A good deal of ironing is still done by hand, but for many articles a mechanical iron is used. This is really a steel ironing board, over which revolves a heated roller. The movement of the roller sends each article on as it is pressed. The heat is secured by steam inside the roller and can be controlled so that it remains constant for a given type of article. The housewife often relies upon guesswork for the temperature of her iron, and is generally using an iron that is either getting hotter or cooler every minute. A thermostat enables the temperature of the automatic iron to be controlled exactly.

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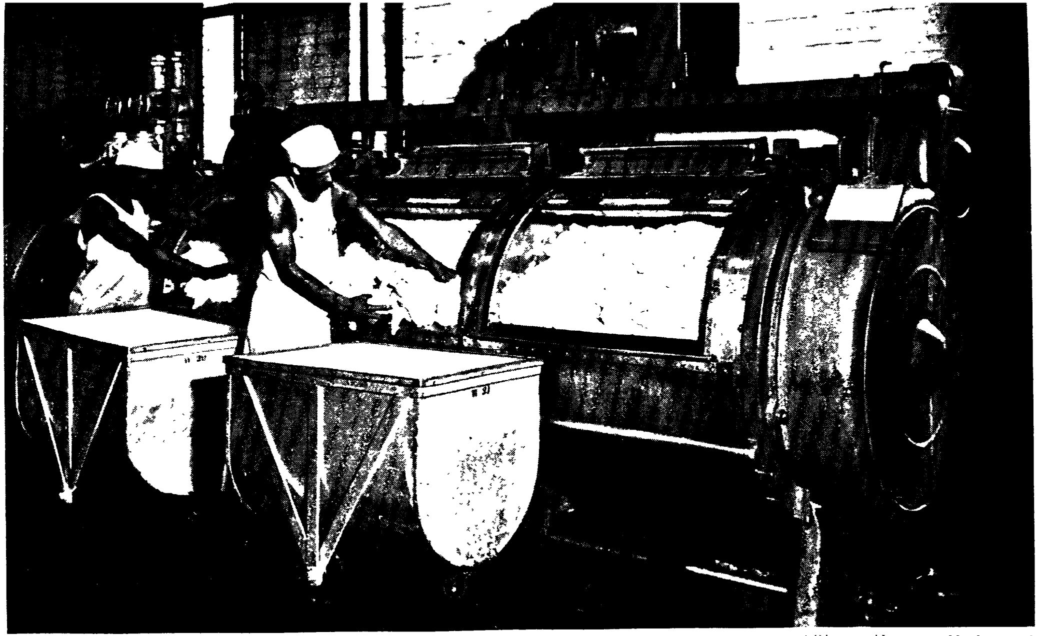

[*Photo: Keystone-Underwood.*

MODERN LAUNDRY MACHINERY.

(The inner perforated cylinder revolves rapidly, and the moisture is forced out by centrifugal force and drained off at the bottom.)

Starching is another matter that is treated scientifically. The consistency of the starch mixture is important, and instead of being guessed it is measured with a hydrometer which takes its specific gravity. Collars and cuffs are starched by machinery, and, as all through the laundry, the machine itself signals by bell or light when it has completed its task.

A linen collar is probably the most difficult article to launder, although silks require careful treatment. The "razor edge" of the laundered linen collar is an old joke, but there is little foundation for it to-day. Ironing is carried out by a series of machines, each attending to a certain part of the process. One damps the edge to prevent creases when it is folded over by another machine, while a third attends to the ironing of the edges. Research has revealed some very interesting facts about the much-maligned linen collar. The length of its life, for example, does not depend so much upon laundering as upon the temper of the wearer. The collar that is habitually "dragged" round when the tie is being tied wears out more quickly than one treated in a sedate fashion.

Another fact is that a moderately dirty collar can be washed many more times without wearing out than one which is much soiled. Greater friction is required to remove any deeply ingrained dirt. All washing, and for that matter all wearing, is a question of friction; your collars wear out for exactly the same reason as your motor-car engine

cylinders wear out. Unfortunately it is not possible to use lubrication on collars. It has even been found that the stiffness of a man's incipient beard makes a difference to the length of the "life" of his collar. During friction minute particles of fabric are destroyed. These are removed so gradually, and are so small that they are not noticed, but one day it is discovered that a collar has "frayed" and its life at an end.

To return to the laundry. After the various treatments, the clothes and other articles meet again in the sorting room. Their owners are identified by indelible marks, and neat piles begin to collect, ready to be packed into their baskets. Each article is inspected, not once but many times, until the collection is finally checked against the list with which it was brought. When you consider that all this is done in two or three days, it seems remarkable, not that occasionally something is lost or injured, but that this happens so rarely. It would be impossible to deal with the dirty clothes of a big city without modern machines and scientific methods.

Closely allied with the subject of laundering is that of dyeing and cleaning. When Perkins discovered the first coal-tar dye he opened up a vast field, the results of which we can see in any store where shelf after shelf is piled high with fabrics of every imaginable hue. New dyes are constantly being produced, and each has to be studied by the launderer to ensure that it receives the correct treatment when any fabric of this colour comes to be washed

Manufacturers themselves make many tests; the launderer and manufacturer have to work hand-in-hand. New fabrics are produced almost as frequently as new dyes, and their washing qualities or proper cleaning are studied most accurately.

Dyeing used to be considered "risky," but it is now possible to say almost with certainty, after an examination of the fabric, whether or not it will take a dye safely. Dry cleaning is really washing without water, and owes everything to chemistry. Liquid solvents for dirt and grease are used as well as purely chemical methods. In any laundry special chemicals are used for removing spots that remain after the ordinary washing. The removal of stains is a highly technical business, each requiring a different treatment. The object, generally, is to find a solvent that will remove the cause of the trouble without damage to the fabric, not always an easy task. To-day, however, solvents for almost every imaginable stain, from tar to ink, are known, and there are very few marks that cannot be removed.

With the conversion of laundering to a scientific basis has come a vast improvement in the appearance of laundries and in the conditions of work for employees. Up-to-date laundries are spotless factories with glistening pipes and tiles. For the women employed the conditions are no longer bad for health. Every one concerned has gained by the application of science to a trade that is as old as clothes themselves.

CHAPTER XIV

PLASTIC AND OTHER NEW MATERIALS

In the average home you will find many materials that are not very different from those of a century ago. There is always the same wooden furniture upholstered with fabric, the same kind of carpets and curtains. But there are other things that, definitely, were not available one hundred years ago. Two materials in particular are now widely used that have only been invented within the last few years, when " plastics " and stainless steel came into service.

Those who first made plastics could not have foreseen the day when the whole solid contents of houses would be made in this way. Plastics are synthetic materials. It is not possible to define them clearly, for they vary considerably in origin and properties, but all plastics have this in common that they are impervious to water. We have plastic ash trays, fruit dishes, electric-light fittings, and many other objects in the majority of homes.

The foundation of plastics was laid when bakelite was discovered in 1907. This substance—the invention of a Belgian chemist, after whom it was named—is made when formaldehyde and carbolic

acid are heated together with a little alkali which acts as a catalyst to help the action without taking part itself. The change is remarkable when it is remembered that both these substances are liquids with powerful smells, while the resulting product is a hard solid with no smell and capable of taking a high polish. The many different synthetic resins used for the manufacture of plastic materials are produced from the same type of substances, and in much the same way, so a description of the manufacture of bakelite must be taken to cover the main principle. The formaldehyde with the carbolic acid are measured in approximately equal parts into a pan which contains a mechanical stirrer and is heated by steam. A little caustic soda is added, and at first the reaction is carried out at a moderate temperature.

An oil separates out in due course, and the thin liquid is filtered off. This oil is heated up and a resin is formed. The treatment of the resin varies very greatly with the purpose for which it is intended. It may be dissolved in alcohol for use in varnishes, or it may be moulded and baked for the making of ash trays and similar objects. Or, again, it may be mixed with a "filler," which may be anything from wood flour to finely ground slate, to increase its strength. The sheets of bakelite so widely used in wireless sets are commonly made with wood flour.

A very wide range of useful things that can be made cheaply and efficiently from plastic materials was shown at an exhibition in London in which a whole room was furnished in plastics. Even the

walls were of moulded plastics ; all the furniture, odd pieces, crockery, and even the clock, were made entirely of synthetic material. It is being said that there are few things made of wood or steel that cannot be made equally well from plastics, and the future may well see a revolution in this direction. It is not suggested that plastics will supersede steel, and it is obvious that for many years wood may be cheaper for certain purposes, but the house entirely constructed or furnished with plastics is by no means a dream. There would be many advantages. Certain plastics, for example, are entirely impervious to weather. The window frames and doors of a plastic house would not need constant repainting. Any colour or design can be imparted to the plastic in a system of moulding which gives a natural high polish. This remains for an indefinite number of years, and all that would be required would be washing.

Serious experiments have been conducted in the production of a plastic of sufficient strength to make the whole side of a house. Plastics rivalling steel in strength and toughness have already been made, and gear wheels for machinery constructed from the same material. One great advantage is that methods of mass production or pre-fabrication could then genuinely be applied to housing. Instead of laying brick upon brick, or laboriously moulding concrete, the builder would have whole sides of a house stamped out for him, and would merely have to fix them upright on secure foundations. Even

such additions as mantelpieces and basins could no doubt be incorporated in the moulding.

There is a very good reason why this policy has never yet been attempted, for the difficulty is that one plastic house might cost a hundred thousand pounds. Several thousand could be erected for very little more, for, once made, the moulds would serve for years. Naturally there is some hesitation in an investment of this kind. Manufacturers must be certain that they have a really safe plastic, and they must be sure that people would live in the houses, knowing how reluctant are most men, or especially women, to experiment. But it seems certain that one of these days we shall watch plastic houses being built, perhaps assembled would be a better description, and completed within a few days. The larger the object to be made the larger the mould, and these moulds are exceedingly expensive. They have to be made of fine metal, and very carefully cut, but already quite large parts, such as motor-car panels, are being constructed.

Plastics have developed very rapidly in the last ten years from the simplest form of bakelite. A variety of chemicals is also used in their formation, many of them originating with coal tar. By the choice of his materials the chemist is able to produce plastics that will have almost any desired properties. Thus, while plastic gear wheels, able to withstand great stress and strain, have been produced, so has a plastic that is sufficiently elastic to act as a substitute for natural chewing gum. Plastics can be

produced in almost any colour or as transparent as glass. One plastic, indeed, has been produced that looks almost like glass. The difference is that it can be carved like wood, does not splinter, and is more transparent to ultra-violet radiation. Optically, this plastic is very much like crown glass, but it only weighs half as much. It is possible that it could be used for everything for which we use glass to-day, from windows to spectacles, although at the moment it is more expensive for some purposes than glass and more liable to scratching.

The forces used in moulding plastics are considerable. In modern practice the filler is mixed with the oily substance produced by the reaction of the chemicals, and the resultant paste is then dried into balls. These balls are milled to a fine powder and fed into a mould, into which fits a die. The mould is heated and the die forced home, usually by hydraulic pressure of anything up to 200 tons to the square inch. The object is thus formed between die and mould, the " resin " first flowing freely into all parts of the mould and then setting hard. Only about one minute is required for this process, after which the plastic article can be turned out, ready for the market, without any polishing beyond the occasional removal of " feather " from the mould. Stainless steel is generally used for these moulds, so that they are always clean, and this is another reason why they are so expensive. The colouring matter is added at the first stage when the oily syrup is formed. The colours are now quite permanent.

For producing plastic panels of great strength, resort is had to lamination. In this method a number of sheets of cotton or paper are impregnated with the liquid resin and pressed together. The resulting board can be pressed or cut to any desired shape. A whole motor-car body or frame could be constructed from this type of plastic, for it is as light as aluminium, heat resisting, and does not give rise to squeaks. Even the windscreen might be made of plastic, and such a car would be very easy to wash. Many parts of modern mass-produced cars are, in fact, already made from plastics ; the famous Ford works have been experimenting with resins prepared from the soya bean, and the filler from the dried beanstalks. A motor car very largely made out of beans is, therefore, a definite possibility of the near future.

Yet another group of plastics are produced from sour milk. It might seem impossible to you that curdled milk could produce an ash tray or an electric light switch, but this is the case. The change is wrought with formaldehyde. The story goes that a chemist trying to catch a mouse in his laboratory set a mousetrap on his bench near a bottle of formaldehyde. The mouse knocked over the bottle, and the chemist was amazed to find next day that the cheese in the trap had turned into a hard glossy substance.

Probably there is no more truth in this story than in many that are told of the origin of great inventions, but at least it is possible. Large quantities of soured

milk are now used for treatment by formaldehyde and the production of a synthetic "resin." Casein becomes a number of useful things, and may be used by builders as a substitute for marble. It is certain that the eye could not distinguish between this marble made by men and cows from that made by nature in the course of the formation of the earth.

The growth of the plastics industry has been remarkable. Until 1924 it hardly existed. To-day it turns out products worth many millions of pounds and employs thousands of people. The vast majority of cheap electric light lampholders and switches are made of plastic material; it is admirable for this purpose because of its good insulating properties. Plastics are light, are not attacked by fruit acids, and therefore useful for picnic sets. The ease with which it is moulded, and the fact that it is not inflammable, makes it possible to produce novelties of every kind very cheaply. We have had the Bronze Age and the Iron Age; perhaps, in the years to come, our own time will be named after one of the most remarkable discoveries ever made.

Articles made of stainless steel are being used in increasing numbers in every home. Very nearly all knives are now made of this metal, and the old knife-cleaning board or machine is rarely seen. The introduction of stainless steel has been a boon to the housewife, for knife cleaning was a regular ritual. What happened was that the steel of the blades of the knives was attacked by rust or acids in food, and the staining was a result of chemical action. When

the knife was cleaned it definitely became lighter, due to the removal of particles of metal. This might not be noticed except on a fine balance, but in time it became apparent by gradual thinning of the knife. Ultimately the knife wore away completely in the middle of the blade. It was not cutting meat or bread that destroyed the knife, but constant rusting of the blade edge.

Rust is one of our most expensive luxuries, and its cost is prodigious. It has been calculated that rust costs the world £500,000,000 a year. This may be an inflated figure, but far more paint is used in preventing rust than in decoration. A big steel structure like the Forth Bridge is continuously being painted; as soon as workmen have finished one end the first has begun to need another coat of paint. Waste does not occur quite on this scale in private houses, but all exterior wood or metal work has to be painted. In the case of many things made of brass, such as water-taps, constant cleaning is necessary to prevent other forms of oxidation.

There are many kinds of stainless steel, but none of them must be confused with chromium plating. The metal chromium has a silvery appearance not unlike polished steel, and a thin coating of chromium is now used on many things, such as bathroom fittings, because it is rust resisting. Real stainless steel is rustless right through, whereas if the chromium plating becomes chipped off the steel underneath will rust. Nevertheless, chromium plating is exceedingly valuable for many purposes.

In stainless steel, chromium is still the most important element, but here it is alloyed with the iron and not used as a coating. Stainless steels for cutlery were found almost accidentally in 1916, and contain about 12–18 per cent. of chromium. The carbon, which, of course, is important in every steel, is represented by about 0.1 per cent., and the steel has the advantage that it can be worked at low temperatures. Many other stainless steels have now been patented, and the chromium content varies up to 60 per cent., with the carbon content rising to 3 per cent. In cutlery it is important that the steel should resist dilute acids in fruit as well as rust, and that it should be capable of taking a satisfactory edge.

Stainless steel is one of the most important materials in use to-day, not only in the house but in industry. Stainless steel for ships, for example, would save thousands of pounds in painting and cleaning. It was reported some time ago that a suitable steel had been found, and that because no allowance had to be made for corrosion the metal to be used in the plates might be 20 per cent. thinner. Iron is not only the commonest, but perhaps the most astonishing of all the metals, because of the remarkable way it enters into loose combination with other substances, including carbon. By varying the carbon percentage by a small fraction a completely new metal is produced, while by adding small quantities of metals, such as nickel, titanium, cadmium, tungsten, and so on, an amazing range is obtained. We call all these alloys "steel," but each

has its special properties. It may be that one is harder than another, or has greater tensile strength, or some other property desirable for some special purpose. Steel manufacturers do not make " steel," but hundreds of different kinds of steel, which vary from one another almost as much as copper varies from iron. All owe their base to the age-old process of smelting by which iron is obtained from the iron-ore deposits which are found in our earth.

Among new materials recently introduced are a number of " rare " metals, and it is quite possible that you use these every day in your house without being aware of their presence. Have you a patent lighter for your gas stove ? If so, it is one of two kinds. Either steel is rubbed against pyrofic metal and a spark produced, or a metal such as platinum, which glows in contact with gas, is held inside a container. The " flint " is probably not a flint at all, but a combination of certain rare metals, such as cerium and lanthanum, with perhaps a trifle of yttrium. It is possible to buy " flints " made of these rare metals for a trifling sum simply because they are a by-product of the gas mantle industry, which uses thorium and small quantities of cerium. The elements used in " flints " are found in the rare earths utilized by the gas mantle industry.

Another interesting new use for a rare metal is in making lead pipes virtually frost-proof. The water-pipe that breaks every time there is a frost is an expense and an inconvenience. It is possible to insulate it with rags or sawdust, so that the frost cannot easily

reach the water, but it has been now found that the addition of small quantities of tellurium, or mixtures of certain other rare metals, including cadmium and antimony, make the lead frost resisting. It is not the thaw that causes the trouble in lead pipes but the frost that comes first. Many people blame the thaw because then is the time when the trouble is discovered. Water occupies a smaller volume than ice. Therefore when the water in the pipe is frozen the volume increases, and the ice breaks the pipe. The strength of the expansion is tremendous, and has been used to crack cannon balls of cast iron.

The rare metal, rhodium, has now been brought into use to make silver that will not tarnish. A very fine coating is given, and there is no apparent difference in the appearance of the silver. The rhodium resists not only corrosion, but acids. The coating is deposited by electro-plating, but will not crack off, even with heat. At present this silver is expensive, but history shows that when a steady demand has arisen for a rare metal the price has generally fallen until mass production brings it within reach of all who appreciate the benefits of science.

CHAPTER XV

HOW OUR CLOTHES ARE MADE

A CENTURY or two ago you could tell more or less how rich a man was by the clothes he wore. To-day that is no longer true. There are still expensive clothes and cheap clothes, but science has been applied so intensively to the art of cloth-making that it is almost possible for the labourer to dress as well as his employer. Perhaps the most striking change that has been wrought is with silk. Even a century ago, silk clothing was a luxury. To-day every woman wears silk stockings, and many men wear silk pyjamas or underwear. From being an expensive and luxurious material, silk has become one of the most popular, available at a cost that would have astonished our grandfathers.

The silk of most stockings and pyjamas is not, of course, "real" silk. A better way of putting it is that it is not natural silk, for it is just as "real" as the silk spun by the cocoons of the silkworm. It is not, in fact, silk at all, but a synthetic product. We call it silk because in many ways, such as softness and wearing quality, it closely resembles the natural silk. But there is no chemical resemblance between the thread spun from the cocoon and the thread

spun by the man-made spinnerets in a rayon factory.

Although experiments had been made in producing thread from cellulose before, it was really the work of the electric lamp pioneers that resulted in the production of modern artificial silk. They were trying to secure a fine thread that would give a firm filament when carbonized ; many squirting and spinning devices were devised at this time. This is a very interesting example of one invention helping another, although the lamp-makers little guessed that similar filaments would one day be used for everyday underclothing.

The great raw material of artificial silk is the same as that for paper. The essential is cellulose, and this may be obtained from different sources, of which the largest is wood pulp, although another common raw material is " linters," the " leavings " on cotton seeds. The wonders of modern invention and manufacture are no better shown than in the pair of silk stockings which a few months ago was part of the trunk of a tree in a Canadian forest.

The first man to make artificial silk was probably Count Hilaire de Chardonnet. Chardonnet made his wood pulp from the mulberry tree, the tree upon which the silkworm feeds. He turned this pulp into nitro-cellulose and dissolved this in alcohol. The solution was then forced, under pressure, through a small hole, when it formed a thread that hardened almost immediately. After manufacture the thread had to be " de-nitrated." The disadvantages of this

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[*Central Press Photo.*

ARTIFICIAL SILK AT COVENTRY.

process can be seen immediately. Nitro-cellulose is another name for gun-cotton, so that manufacture carried certain risks. In practice this silk was more expensive to make than real silk. Nevertheless the process was improved, and later on cotton was used instead of mulberry wood pulp. Many millions of yards of silk were manufactured by this process, which is still used; but it is obvious that the supply of cotton linters upon which it depended was limited, and that alcohol or æther were too expensive as solvents to be ideal. Two other processes have now come into use.

In the cupro-ammonium process the solvent is a solution of copper-hydroxide in ammonia, known as Schweizer's reagent. The cotton is first mercerized by being treated with strong alkali and then dissolved in the cupro-ammonium solution. The process of dissolving, assisted by mechanical stirrers, takes about six hours, after which all the cotton has disappeared into the deep blue liquid. The thread is spun from fine jets and drawn up through the bath on to a bobbin. The silk is freed from any copper that may remain by being passed through a bath containing very weak sulphuric acid. Transparent wrapping paper is made by a very similar method.

With the third, or acetate process, the solvent is acetone, a substance that was largely developed during the war as " dope " for aeroplane wings. It had been known for a long time that it was suitable for silk manufacture, but it needed a war-time scale of production to make it a commercial proposition.

The cotton in this case is treated with acetic anhydride before being dissolved in the acetone. This is not a cheap solvent, but methods have been developed where, by refrigeration and absorption, only about one-tenth of the acetone is lost during manufacture. The same acetone can, therefore, be used over and over again.

Only about one-seventh of the world's artificial silk is now produced from cotton. The remainder comes from wood pulp, which is first mercerized and then finely shredded. After this the pulp is allowed to mature, an important step upon which depends the viscosity of the ultimate solution. The pulp is treated with carbon bisulphide, and the resulting gelatine-like substance dissolved in sodium hydroxide, when it is ready for spinning. The thread has to be thoroughly washed and bleached. The complicated chemical changes that take place are not yet fully understood, but are still the subject of strenuous research.

The manufacture of artificial silk is an interesting example of chemical and engineering invention working together, the chemical invention so often being slightly ahead. Chemistry is concerned with the production of a solution from which a thread can be spun. Engineering has to produce suitable spinning apparatus. The quality of the thread depends upon both. The most careful control must be kept over the temperature and strengths of the solution, while the greatest ingenuity has been lavished on the manufacture of spinnerets. These

are made of some chemical resisting metal such as platinum or palladium, and can be made so fine that the resulting thread is thinner than the finest silk. The spinning may be either " wet " or " dry." The wet process, in which the thread is deposited in a bath, is more commonly used to-day. The spinnerets are immersed in a bath of setting liquid, and the thread, as it emerges, is passed over a roller and down a funnel into a box which rotates. The thread is thus given a twist and does not require stretching. In the dry spinning process, used for Chardonnet silks, the thread is stretched as it emerges, so that a fine thread is drawn out yet finer.

It is usually desirable that silk should have a good lustre. Part of this comes from the shape of the thread itself. Under a microscope you might see that the thread was not perfectly circular, but saw-edged. The reflection of light from these ridges produces the lustre. To secure this shape various substances are added to the setting bath, and the lustre of your silk stockings may well be due to a " lump " of sugar. Much research has been lavished on the dyeing of artificial silk, and wonderful results obtained. By using a mixture of silk and cotton or wool it is possible to produce remarkable colour effects, for the silk may be affected by a certain dye which leaves the cotton or wool untouched. It is in this way that " fur fabrics " are made.

If artificial silk is the most modern of the materials from which our clothes are made, it seems likely that wool is the oldest. Skins, which were the

first clothes of men, at any rate in cold and temperate regions, are simply wool held together by the skin. But even in the manufacture of wool science now plays the principle part. Perhaps it is difficult for us to realize that there was a time not long ago when it took weeks to make sufficient cloth for one suit, and that the average man could have but few changes of clothing. Until the invention of automatic machinery for spinning and weaving, good clothes were a sign of wealth. Machinery has brought good cloth within the reach of all. Wool is found in every man's suit. The world's consumption of wool is now approaching the tremendous figure of 2,000,000 tons a year. To appreciate this figure, remember that a man's suit weighs only a few pounds, and the wool in it is often mixed with other fibres.

The contributions of science to wool manufacture, apart from inventions relating to spinning and weaving, are considerable. At the very beginning there is the breeding of special sheep to give the finest fleece. The study of heredity has enabled scientists to hasten the process of evolution and direct it into the channels that have been found most useful. Natural evolution is not always towards the best, but by careful choice of "stock" or parents, and even by gland grafting, scientists have been able to produce the cow from the wild ox, the beautiful racehorse or the massive carthorse from the wild horse. When we speak of domestic animals being descended from certain wild species we should realize that the wild animals

[*Photo: Keystone-Underwood.*

MAKING RUGS FROM SHEEPSKINS.

(A quaint hand trade in an old corn mill at Tutbury, near Burton-on-Trent.)

e know to-day are not the same as the original ock from which domestication began. There are ild sheep in the world to-day, but they probably e very different from those first tamed by man.

The finest sheep bear a fleece many times eavier and finer than the sheep kept by the farmer f a few centuries ago. Some sheep are bred for oth flesh and wool; science has even been able keep pace with fashion by breeding a sheep iving small joints such as are in demand in the mall families of to-day. No doubt if the demand hanged, big sheep would soon be forthcoming.

Mechanical clippers greatly speed up the shearng, which is the first stage in the manufacture of vool. A man with a mechanical shears can deal with ibout eight times as many sheep in a day as in the ase of hand clippers. The fleece is removed whole, ind the task of sorting the different qualities of wool s still carried out by hand and eye. From this time, iowever, until it appears as a length of worsted, the wool is dealt with almost entirely by machinery.

There are many steps in the process, of which washing is one of the most important. A fleece contains grease, and this must be removed. Then, as the sheep feeds in the open, there are probably small pieces of vegetable matter to be removed, and this also is done mechanically. The next step is to "card" the wool, that is to say, rearrange the fibres so that they all lie the same way. The same process is necessary with other fibres, such as cotton or flax, which are used for spinning a thread, and the

we know to-day are not the same as the original stock from which domestication began. There are wild sheep in the world to-day, but they probably are very different from those first tamed by man.

The finest sheep bear a fleece many times heavier and finer than the sheep kept by the farmer of a few centuries ago. Some sheep are bred for both flesh and wool; science has even been able to keep pace with fashion by breeding a sheep giving small joints such as are in demand in the small families of to-day. No doubt if the demand changed, big sheep would soon be forthcoming.

Mechanical clippers greatly speed up the shearing, which is the first stage in the manufacture of wool. A man with a mechanical shears can deal with about eight times as many sheep in a day as in the case of hand clippers. The fleece is removed whole, and the task of sorting the different qualities of wool is still carried out by hand and eye. From this time, however, until it appears as a length of worsted, the wool is dealt with almost entirely by machinery.

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method is much the same in every case. The mass of tangled wool is passed through two rollers working against each other. On the surface of the rollers are fine wires which only pass the fibres in one direction.

The wool is then spun into a thread; but this is only the beginning of a piece of cloth. For many reasons it may be desired to blend wool with cotton and silk, or different kinds of wool may be blended together. After weaving, woollen cloth is subjected to mechanical brushing to bring up the "nap," and it has then to be shrunk before leaving the factory.

The cloths woven at cottage doors by women hundreds of years ago were often very strong, although they must have been uncomfortable to wear next the skin, but they were necessarily of uneven quality. These picturesque days have passed, and to-day turning wool into worsted is more of a science than an art or craft.

Although wool is considered to be the oldest material for clothes, cotton is the most important, for it is used for clothing in every country of the world. Cotton is a fibre grown by a particular group of plants to protect their seeds. Although cotton cloth was woven in ancient Egypt and India, science has contributed greatly towards improvements, and it is certain that the present huge world demand could not be met without the help of progressive methods, even before the crop is harvested. About fifteen years ago the boll weevil threatened to destroy the entire American cotton plantations. A scientific

war was waged on the pest, and, chiefly by poisoning with arsenic compounds, it was defeated. The trouble still exists, but it is definitely under control.

Aeroplanes, now quite an ordinary part of agricultural equipment, are used for scattering the poisonous powder over the crops. In Russia aeroplanes have similarly been used for sowing seed, and a single 'plane has been able to perform the work of many horse- or tractor-drawn drills. Speed is all-important in dealing with insect pests or with sowing when conditions are suitable.

In one of the first processes the cotton has the seed mechanically removed in a "gin," and is then transported to the mills, where the processes, as with wool, are combing and carding. By a series of machines the cotton is spun into a finer and finer thread. It is spinning that gives the cotton its strength; the straight fibres have little power to resist tension. Ordinary sewing cotton is made by twisting a number of the finely spun threads together; the number of threads used depends upon the strength required.

Every housewife is proud of her linen, and rightly so, for, apart from its beauty, good linen wears longer than any other material. The woven fibres of flax dispute with wool the title to be the oldest material used by man, and "fine linen" was always a sign of luxury. Although science has greatly changed the treatment of the fibres it has not been able to make linen really cheap. The fibres used

surround a soft pith, and to separate them the pith is rotted.

Scientific methods of doing this by soaking the flax in warm water have been devised, but much of the flax is still treated, as it has been for centuries, by allowing it to lie in the open or in a stream so that the pith becomes decomposed. When the flax fibres reach the factory they go through processes similar in principle to those for wool and cotton. The fibres are combed, carded, and then run together repeatedly by machines until the fibres are perfectly distributed. Finally they are spun together to secure the necessary strength. Although in large factories this is done by machinery, linen making is one of the crafts that has most successfully resisted the advance of the machine; especially on the continent a vast amount is still spun and woven by hand.

Real silk, when silkworms spin out the delicate fibres, may seem to be the product of unaided nature, but, in fact, this thread is controlled by science quite as much as any other. The worms do the work for us; they turn the cellulose of the mulberry tree into a fine thread in a way we cannot achieve in the laboratory. But they are watched at every stage of their life. Constant breeding under artificial conditions has resulted in the silkworm becoming delicate and subject to many diseases. It might have been wiped out altogether but for our knowledge of chemistry, bacteriology, and biology that is used for preserving these little worms. The great

French scientist Pasteur not only showed how to guard the lives of men and women threatened with hydrophobia and other diseases ; he also saved the silk industry of France. In the East, where silk has been made for countless centuries, technical methods have at last begun to replace those of history.

Silk thread does not need to be combed and carded like wool and cotton, but this process is applied to the fluffy silk found in the centre of the cocoon to give us " spun " silk. To increase the weight of silk, chemicals are often added, and chemicals are also used in the treatment of raw silk to make it white or glossy. The weaving is carried out as with any other thread, and has been mechanized in the same way.

These are the chief materials from which our clothes are made. Many people imagine that scientists believe clothes to be of no importance, but, considering the millions of people employed in growing or manufacturing the raw materials and the great amount of thought given to the subject, the industry is another excellent example of educated progress.

CHAPTER XVI

GLASS AND FURNITURE

It is difficult to imagine a house without windows, yet in fact glass windows are a comparative innovation. Although glass was known to the ancients, and was used for windows long before the Norman Conquest, it was not until centuries later that it became common for windows in England. Much more recently people showed how little they appreciated the value of windows by taxing them severely. Naturally, under such circumstances, householders began to wonder if they could not do with fewer windows, and quite a number were blocked up. In some old houses you will still see the bricked-up spaces which resulted from this foolish tax.

To-day we appreciate the true value of windows in admitting light, and special glasses have been invented which transmit not only the visible rays of the spectrum, but also the invisible ultra-violet rays which are so valuable to health. These types of glass are often used in railway carriages, sun lounges, and nurseries.

Within the compass of one house a number of different kinds of glass are to be found. There is the glass that is used for glazing the windows, the

glass that is used for tumblers, perhaps some glass that is merely decorative, and in the garage you will find glass in the car which is "unbreakable." Then there is the very important glass from which electric lamps are blown. These are but a few of the many types now made, each with its special use. One of the most important branches of this industry is the production of optical glass. This is used for making not only your spectacles, but also lenses for cameras, telescopes, opera glasses, and cinema projectors.

The composition of glass depends upon the purpose for which it is to be used, but the essential ingredient is silica. Pure silica itself yields a kind of glass, but this is rarely used except in laboratories, where it has the very great advantage that it will withstand not only high temperatures but very quick changes in temperature. For most glass something is added to the silica, and upon the proportion and nature of the substances added depends to a large degree the qualities of the final product.

In ordinary window glass, for example, lime and soda are added. To produce fine-cut glass, potash and lead are mixed with the silica, or a small amount of some elements will produce some particular colouring. Ruby glass is made by mixing either a gold or a copper salt. Chromium produces green glass, and so on. A number of compounds are used to produce Crooke's glass. This has the property of cutting off some of the harmful rays of the spectrum while freely transmitting those that are necessary for clear sight. Spectacles made with these glasses

will prevent glare, whether it is due to direct sunlight or reflection from snow, from reaching the eye.

The first stage in making any glass is the mixing and fusing together of the materials. The sand or flint is stirred with the lime and soda or other materials, and heated in a suitable container made of fire-clay to withstand the heat. In some cases an open furnace is used, but in most works the heating is carried out with producer gas from coal or coke. In making optical glass continuous stirring is necessary, and in the production of any glass a considerable amount of gas is given off. To prevent this forming bubbles in the glass, which would spoil its quality, a little moisture is introduced to the molten mass, sometimes in the form of a newly cut potato. Steam is given off, collects the bubbles of gas, and brings them to the surface. Only heat is required to produce ordinary glass, which is then ready for the glass-blower or whatever other treatment may be necessary.

A great deal of glass is blown, and even window glass may be produced by this method. The glass-blower makes a large hollow cylinder of glass, which is afterwards cut down in length and then flattened, but in these days most of the common glass products are produced by machinery. Very ingenious machines have been invented for making bottles. The arms of the machine pick up just the right quantity of molten glass, which is blown out into a mould. Window glass in large sheets is produced by machinery, the glass being poured on to a large

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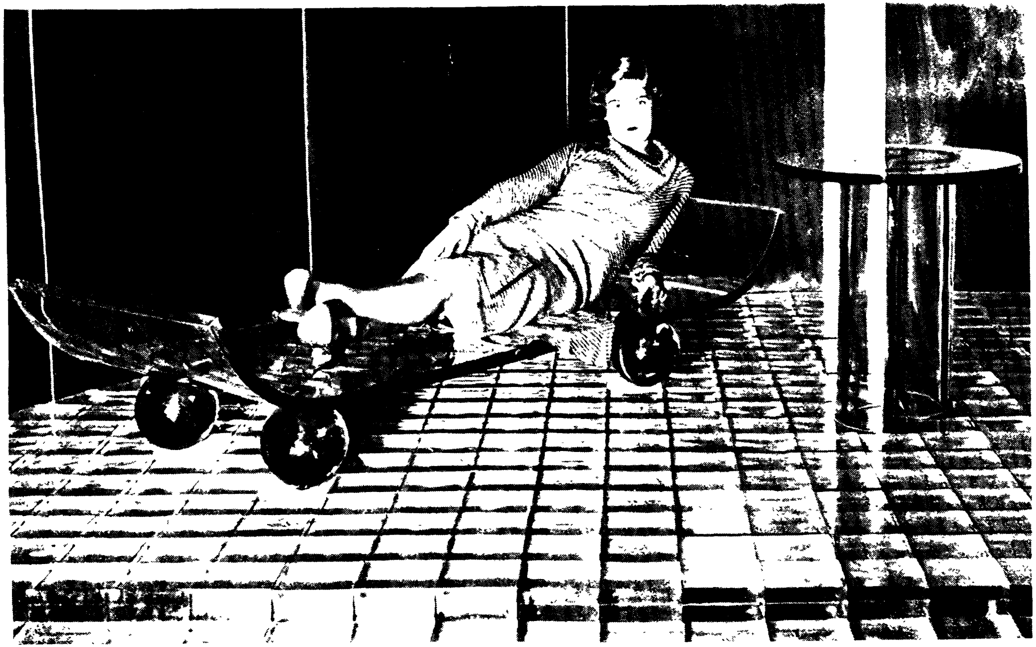

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[*Photo: Keystone-Underwood*

MODERN GLASS FURNITURE.

flat table and rolled. It may afterwards have to be polished by machinery, and almost certainly will be annealed in a furnace.

As important as the heating of glass is its cooling. When anything has been made of glass, whether it is a sheet of window glass, a bottle, or the glass for a spectacle lens, it has to be cooled slowly to prevent stresses, which might result in cracks. In the case of optical glass, the cooling process may take several weeks, and in the case of a big telescope lens, several months. A new telescope lens which has been made after great difficulty in America may take over a year to cool.

Many new kinds of glass are now being produced and new uses found for this substance. One of the latest is the actual building of houses from glass bricks. The bricks are made hollow so that they have the effect of being sound and heat insulating. Already, in America, an office building and a private house have been made of glass bricks. The bricks are as strong as those made in the ordinary way from clay, far easier to clean, and very much more decorative. Instead of being joined by mortar, these bricks are welded together with thermit, an aluminium mixture which produces a very great heat. The whole wall of glass bricks, therefore, is a solid mass of great strength.

Another new production is glass wool, which has insulating properties. It may be used in house building to pack partitions to prevent sound penetrating. It also insulates against cold and heat. A

little glass will produce a very great deal of wool, which is, as its name suggests, a very fine " fibre " of glass. The glass in an ordinary milk bottle, for instance, would produce a thread six thousand miles long. Already such glass wool has been woven, and women are wearing glass dresses. Curious as it may sound, a glass blanket makes a light and effective covering because of the great insulating power of the contained air.

Motor cars have made us all familiar with " unbreakable," or perhaps it should be more correctly described as unsplinterable, glass. There are various ways in which this can be made. A sheet of celluloid is sometimes cemented between two layers of glass so that it becomes invisible, but it is also possible to make a glass that will often resist the impact of a bullet. The strength of this glass depends upon the way in which its molecules are arranged, and the curious fact is that although a bullet fired at a plate of this kind would fail to penetrate it, a tiny scratch with a diamond ring would shiver it to small pieces, as in the case of ordinary toughened windscreens. These are made from glass that has been cooled outside more quickly, so that each part is under separate strain.

We are apt to think of glass as rather a fragile material, but this is not really correct. It is one of the hardest substances in the world, and can only be matched by diamond-hard minerals or special steel. So it is very useful for floors. It will wear out many thousands of pairs of shoes without

itself showing any appreciable wear at all. In ordinary houses glass floors are not yet popular, perhaps because they are too expensive; but if we have a basement or a cellar under a street we usually cover the skylight with blocks of glass which reflect a certain amount of light, but are quite as hard as the surrounding pavement. Glass for roads is already being tested.

Glass is unaffected by all common acids, and by normal temperatures. This is what makes it so ideal for domestic glassware, where its one disadvantage is that it is fragile. Although glass is not attacked even by strong nitric or sulphuric acids, it is soluble in hydro-fluoric acid, and this fact is made use of in etching. Glassware may be decorated by etched patterns; acid bottles in the laboratory usually have the name of the acids they contain etched directly on to the glass, because any drops of acid that spilt would quickly eat away an ordinary label. This etching is carried out with hydro-fluoric acid applied through a stencil. Wherever the acid touches the glass it eats it away, the parts that are not wanted to be touched being covered by some suitable wax.

Most houses with a garden contain a greenhouse, and here glass is essential. It passes the light without admitting the excessive cold. If glass can be used that transmits the ultra-violet rays instead of cutting them off like lead glass, so much the better. The plants which we grow in the greenhouse on a small scale are grown in thousands by the specialized market gardener. In some parts of England, such as

the Lea Valley to the north of London, and the country around Worthing, acres and acres of land are completely covered by glass. In these huge glasshouses early vegetables, tomatoes, and lettuces are grown, and it has been found that the type of glass used has a noticeable influence upon the rapidity or coloration of growth.

By keeping out the cold and making use of the sun, the gardener is able to cheat the weather. Formerly, if we wanted summer vegetables in March, or roses at Christmas, we had to depend upon imports from sunnier countries. A few years ago we bought in over $4\frac{1}{2}$ million pounds' worth of tomatoes a year, and $1\frac{1}{2}$ million pounds' worth of flowers. Now, by the scientific cultivation of plants under glass, we are able to grow much of this at home. Under glass, farming is carried out almost as in an open field. It is possible to use horse ploughs in the largest greenhouses, which have many thousands of panes of glass for their roofs and sides. The demand for panes has led to their rapid production by machinery, and some of the finest machines can turn out about one thousand square feet of glass, cut to size, every hour. In this machine the glass flows through rollers. It is kept moving continuously, and as it cools it passes under another roller on which are fixed a number of diamond cutters. These scratch it at the desired point, and only a light tap is necessary for the huge sheet to fall into panes of exact size.

The farmer's greatest enemy in under-glass

cultivation is a heavy fall of hail, which may break hundreds or even thousands of panes in an hour, ruining the crops growing underneath by admitting cool air, and costing a considerable sum for renewal. "Unbreakable" glass is, unfortunately, too expensive to use for this purpose at present.

We have our fields under glass; we are becoming gradually less and less dependent upon the weather for food or flowers. In time we shall probably put our roads under glass, certainly our largest cities. It will then be possible to walk from the station to office or home without getting wet, or without avoiding dirty puddles, snow, and wasteful fog.

The value of glass is not merely that it is transparent, but that it is easily blown and drawn. It is blown to form the lamp which contains the filament of electric light, and it is drawn to form the long tube in which gases are subject to an electric discharge to make illuminated signs. The production of these tubes is still carried out by hand, and the glass blower is usually a very skilled operator. It is possible to draw out a tube several hundred feet long, and the curious thing is that however long it is drawn the tube will nearly always remain hollow.

Glass is a material for which we are finding new uses every year. To-day, for instance, we cover our dressing-tables and our desks with large sheets of plate-glass, which resist the heat and are very easily cleaned. We use special glass, which can withstand quick variations in temperature, for cooking, and by placing plate-glass in the door of our ovens we are

able to see what is going on inside without opening the oven to spoil a cake. The amazing varieties of glass that can be produced by varying the ingredients of the original mixture and by the subsequent treatment enable the chemist to make almost any required type. In this respect glass begins to resemble the plastics with which one day it may be combined to our great advantage in the manufacture of furniture.

The day has passed when wood served England in the walls of ships, but it is still a commodity of vast importance. Wood has helped to produce coal in ages gone by. It serves us still in mining, in our houses, our furniture, and our arts.

There are countless uses for wood in its many forms, while in combination with various "synthetic" materials it is being made into anything from decorative pictures to acoustic linings as a protection against noise. In tens of thousands of tons wood is pulped to make your daily newspaper; it may yet become a basis of water- and draught-proof clothing. In these and other forms the consumption of an ordinary house may represent the output from quite a little forest of healthy trees.

The world of furniture is an interesting example of the application of modern methods to one of the earliest raw materials in the world. Many people are still prepared to pay large sums for antique furniture, often of doubtful beauty, but the most astounding point is that a hundred pounds will now equip a whole house with well-designed wood furniture.

This has been made possible by mass production. It would seem at first that such processes as carving, mortising, and so on would have to be performed by hand. Joining wood is a laborious business, even for a skilled carpenter. It is only machinery that enables all furniture to be sold as cheaply as it is to-day.

From the very first the logs are sawn by machinery. Tree-felling is still carried out by hand, but portable machines have been invented for this purpose. Circular saws are used for ripping the log into suitable planks. Generally these saws are driven by electricity, owing to ease of control. The operator has merely to move the various guides to the required positions and the saw does the rest. When cutting with the grain a pendulum ripping saw is used. The planing of the surfaces is entirely mechanical. A single planing machine can deal with between 250 and 300 feet of wood a minute. It might take a man with a hand plane a week to do this work, and unless he was a great craftsman the accuracy might not be so good. For cutting curves a machine-operated vertical band-saw is used. Even sand-papering and polishing is carried out mechanically.

Carving is carried out by a wonderful machine which can duplicate anything from four to thirty-six carvings at one time with only one man in attendance. Machines are used for binding and gluing when veneers are required. Three-ply wood is extensively employed to-day; it would not be so cheap if the whole process of cutting the thin slices

and gluing them together were not carried out by automatic machinery.

In America efforts have been made to develop the manufacture of furniture by methods of mass production, using conveyer belts. The various pieces, cut to size, pass along the belt to a number of operators, each of whom performs some operation, until at the end of the run the chest of drawers, chair, or whatever it may be is ready assembled.

Science plays a part even in the manufacture of hand-made furniture to-day, and the Forest Products Research Laboratory is constantly at work testing timber. Where the old craftsman relied on experience and instinct, we have exact scientific tests, and can know every detail of the material from tree to fireside.

CHAPTER XVII

IN THE GARDEN

A HOUSE without a garden is only half a house, and even in these days of self-contained flats, most people like growing flowers in pots or cultivating window gardens. Originally the garden was of great importance in providing a house with food. Nowadays, when market gardening is done on a large scale so that even home vegetable growing is more interesting than profitable, most men still like to cultivate something. The instinct is almost as old as that of the hunt.

To many, gardening is more of a pastime than a science, yet nowhere is knowledge more necessary than in the preparation of flower-beds. The soil is an amazing chemical or physical laboratory, and the plants perform intricate "experiments," many of which have not yet been successfully imitated in the laboratory. A knowledge of chemistry makes gardening not only more interesting but also more profitable. Most gardeners work by rule of thumb without worrying over the "why and wherefore." For this reason they are apt to make mistakes. In using chemical fertilizers, for instance, not a few kill as many plants as they feed successfully. You

may be a born gardener or a born mother, but a little scientific knowledge improves the chances of both plants and babies.

In the garden, and in the fields, all our food is made. Without plants the human race could not survive. All our animal food, meat, eggs, butter, milk, comes indirectly from plants. Animals do not make food. They merely turn vegetables into other forms. The grass could survive without the cow, but hardly the cow without the grass. In the vegetable garden certain chemicals are combined by the action of sunlight to form living things, and it is upon these living things that we depend for all we eat. We can make a few chemical foods in the laboratory, but for ninety-nine per cent. of our foodstuffs we depend entirely upon plants.

The food consumed by plants covers a quite surprising range. They "eat," in addition to air and water, lime, potash, phosphates, iron, nitrates, and magnesia. Every gardener knows that plants must have air, sunlight, and soil. The sunshine provides the energy—energy, incidentally, which eventually finds its way into our bones, so that when we eat a pat of butter we are probably using up some of last month's sunshine. The chemical that plays a most important part in these changes is called chlorophyll, and provides the characteristic green tint of all plants. If you keep a plant in the dark, or "blanch" it, like celery, it remains white. Chlorophyll is a complicated chemical that organizes the extraction of carbon from the carbon dioxide in the air. The

little grains of chemical perform this work with apparent ease, but it can only be done in the laboratory with difficulty. Plants, incidentally, clean the air for us.

Growing plants differ from animals in that they cannot go far in search of their food. The food must be brought to them. They may send roots shooting outwards, or the stem may climb to great heights in order to get sunshine, but, generally speaking, their food must be close at hand. It is making sure that this food comes to the plant that is the art and science of gardening. Plants, for example, take up oxygen through their roots. This is one reason for the constant digging and hoeing carried out by the gardener. Plants must have water, and so we must grow them within reach of the rain or water them artificially. This also is another reason for hoeing. Plants do not take up water through their leaves, rather do they give off moisture so as to keep a constant current of liquid running up the stem by " surface capillary " action, with food from the roots below. It is useless, therefore, to water the leaves of a plant in very dry weather except as a refresher. The water is wanted at the roots, and the ground about them must be soaked. It is little use sprinkling the water, for this will only wet the surface and result in the roots coming upwards to get at the liquid. As soon as the soil dries the roots are parched even more than before. The movement of water in soil, however, is normally upwards. It trickles and filters through the ground, and then begins to rise by capil-

lary " pumping " action. By constantly breaking up the top of the soil we prevent the water reaching the surface and being evaporated. The same object is achieved by placing a layer of insulating material, such as grass cuttings or strawy manure, on the surface. Gardeners call this " mulching," and know that in a drought it is more effective than any but the most wholesale watering of the ground in keeping roots supplied with water. Very few, however, consider the reasons for these effects.

A plant takes its food through the roots, and these are of prime importance. Therefore, in growing bulbs in bowls, for instance, they are placed in the dark for some weeks. The roots grow and become strong, but the leaves do not begin until the plant is moved into full light, by which time the roots are well developed. Normally, the bulb is planted some inches deep in the soil, and the roots have plenty of chance to become established before a shoot reaches the surface. To try to force the growth of a plant before it has good roots is like getting up steam in a locomotive without being certain that there is plenty of coal in the tender. Roots are strange things. They will show a liking for other similar roots; they will destroy plants for which they have a distaste; they will find their way to soil they need through heavy concrete when no other path is provided.

The method by which roots make use of the chemicals in soil is very complicated. It must be understood that the roots live only on chemicals,

[Fox Photo

WATERING ON THE SOIL, NOT ON THE FOLIAGE.

that is to say, on so-called dead things. Although it may sometimes appear that they obtain food from living material, except in the case of a few parasites it is always chemicals that are used. This is the wonder of plant life, the continual turning of the apparently inorganic into the organic, a seeming creation of life out of dead things. In this the plants are helped very considerably by a multitude of bacteria in the soil. It is, in fact, doubtful if the word " dead " is ever accurate in this world.

We are apt to think of germs as evil things. We associate them with measles, colds, and other diseases, but often they perform many useful tasks, and on the whole as a race they are more useful than harmful. At any rate they are essential. They can, for example, bring about chemical changes in dealing with the fermentation of vinegar. In the soil they assist the roots in taking up chemicals, and a sterilized soil would be completely infertile, although a partial sterilization to remove harmful bacteria is often carried out.

One of the most remarkable groups of plants are the leguminosæ, which include peas, clover, lupines, and other similar plants up to the number of about 7,000. If you examine the roots of one of these you will notice that they are covered in nodules. It is only comparatively recently that their work has been understood. With the aid of bacteria these plants have the special gift of taking up large quantities of nitrogen from the air. The bacteria or vegetable parasites " fix " the nitrogen of the air

and make it into a food suitable for the plants. Although nitrogen is an essential food of plants, they cannot assimilate it directly. To-day, chemists "fix" the nitrogen of the air by using a catalyst, such as finely divided platinum, and thousands of cubic miles of air are turned into nitrates every year. Nature carries on this same work, to a degree, by lightning, which manufactures an appreciable amount of nitrates every twelve months. These nitrates are dissolved in the rain, carried down into the soil, and help to account for the special greenness of grass after a thunderstorm has also increased the activity of atmospheric oxygen.

The action of nodules in leguminous plants has been the subject of much research. Farmers knew that by growing a crop of clover or peas they could actually enrich the soil with nitrogen, even if they did not understand the reason. We now know that the successful action of the clover depends upon minute organisms, and that their absence explained why a leguminous crop sometimes failed in its action. The next step was to ensure the presence of these bacteria by adding them to the seed before planting, and this work is now actually performed.

The soil which is so essential to plant growth consists of a mixture of many things, but, broadly, its constituents can be divided into a few classes. First of all there is the humus, which is really decayed animal and vegetable matter. When we add farm-yard manure to soil we not only provide the plants with the chemicals they require, but also add humus

that may be necessary. Chemical manures or fertilizers will never, of course, add humus, although several synthetic manures, making use of such products as exhausted brewers' hops, have been produced. Sometimes gardeners manure a patch by growing on it a crop such as mustard, and then digging it in. The decaying plants provide valuable humus.

Soil also contains mineral matter. By the action of wind, rain, and frost little pieces of rock are broken off, broken almost to powder, and incorporated with the soil. The exact composition of the mineral matter varies widely with different localities. Sometimes it is the mixture we call " clay," sometimes the ground we call " sandy."

Then there are the chemical constituents which provide the actual food, and of these the most important is chalk or lime. Whatever other food a gardener refuses his plants, he must give them lime, for without it the other chemicals are not brought into a state fit for the plants to consume. Many tons of chemical fertilizers are wasted every year by being added to soil deficient in lime. If you wish to see whether the soil in your garden is short of lime, take a few samples from different parts of a bed, dry them, and then add dilute hydrochloric acid, the ordinary commercial spirit of salt will do well. If the soil " fizzes," due to the evolution of carbon dioxide gas, there is no deficiency, but if it does not " fizz " this means that there is very little lime in the soil, and a dressing of chalk or slaked lime is indicated.

Lime is particularly necessary in large towns, where the soil becomes " sour " by the addition of chemicals from fumes and smoke in the atmosphere.

We are apt to think of " soil " as something permanent, as something which has been there since the world began, and to believe that it will always be the same. This is a false picture. The soil is a continually changing laboratory. It was not there when the world began. One can imagine that when the rocks began to cool pieces were broken off by the action of water, wind, and cold. These pieces would collect where they were protected from the wind. The first simple plants grew and died, their skeletons forming the original humus. The soil was built up little by little. It was helped by great rivers bringing down fertile mud. But the soil was manufactured, and the manufacture must have taken many thousands, perhaps many millions, of years. Even in your own garden, although the soil may look the same to-day as it did this time last year, it is really very different. Something has been added; something taken away. The plants are always taking away, and the gardener, therefore, must always be adding something. Such is the natural power of the soil to restock itself, helped by chemicals washed down by rain, that provided it is not allowed to run short of lime it will continue to give crops for years without the addition of artificial manures.

At present the shortage of animal manure is such that most gardeners and farmers use chemical fertilizers. There is much unnecessary prejudice

against "artificial" or "synthetic" materials, but chemicals cannot take the place of humus. There are hundreds of chemical manures, but they mostly fall into three classes—nitrates, phosphates, and potash. Many of the fertilizers are mixtures of two or three of these groups, and the action of each is different. All three are required for the successful growth of a plant—the gardener should supply that which is necessary for his particular purpose.

Nitrates are associated with the rapid growth of leafy material. Their action is remarkably quick, and if nitrate is added to the soil to-night the effect is visible after the first shower of rain in the rapid growth and darker colouring of the leaves. Gardeners use nitrates when they wish to promote a leafy growth, as in cabbages, spinach, and other edible plants. Many amateurs add too much. Plants are like children and do not know when to stop eating. The results of overeating are as disastrous in plants as in people. It is easy to kill plants by over-fertilizing, and this is particularly the case with nitrates. Gardeners are usually given instructions to add so much to every square yard, but very few ever weigh out the quantities of fertilizer or measure the square yard. If they realized that they were bringing about a definite chemical action, they would, perhaps, work more precisely, although it is not at all necessary to be accurate to a hundredth of an ounce.

Phosphates promote the growth of seeds and fruits. They will help all those vegetables of which

we eat the seeds, such as peas and beans. They can help roses to bear bigger and more frequent blooms. A wide variety of phosphates are used, some more soluble than others. The insoluble phosphates may be soluble in soil water, but their action is slower, which may in some cases be desirable. Phosphates are also found in such "natural" manures as guano and bone meal. Guano is the hundreds-of-years-old droppings of birds which lived in certain very dry areas of Peru. Fish guano, which is now frequently sold, is the treated remains of fish from large factories. Nitrates originally used to come from South America where there are huge natural deposits, but the great demand (for nitrates are a basis of explosives as well as fertilizers) resulted in synthetic methods of production, including the fixation of atmospheric nitrogen.

Potash stimulates the root growth and results in giving the plant better health all round. A small percentage of potash is found in wood ash, and it is for this reason that gardeners add the remains of their bonfire to the soil. Burning wood is, however, a very extravagant way of making a fertilizer, because much of the potential food value is lost in the smoke.

Vast quantities of artificial fertilizers are made every year, and the quantity increases as the number of horses providing natural manure decreases. Recently, experiments have been made in the production of entirely artificial soils. It is said that by using these soils under controlled conditions it is possible to grow crops in one quarter the time, and

in much less space. It is suggested that the garden of the future may consist of a huge filing cabinet in which each drawer is a " bed," pulled out when the owner wants to pick some vegetables or flowers. Fantastic as this may sound, it is by no means impossible now that we are gaining exact knowledge of the soil, its electric treatment, and its many strange constituents.

The seasoned gardener is often apt to think that technical talk is " so much theory," and he continues to use his rule of thumb methods. But these principles are the result of centuries of practical experiment and tradition. In many cases practice has shown chemists the method of investigation. In others chemists have enabled practice, based upon pure trial and error, to be improved. Both theory and practice are necessary in gardening, and while no chemist could experiment without some practical knowledge of the actual growing plants, no gardener should be without what too often is called mere " theoretical " knowledge.

We have seen the vital importance of chemistry in gardening. In every garden chemistry and biology meet, and it is often impossible to mark any line of division. But the science of living things is so great that its study is literally in its infancy. How food is utilized by the innumerable cells of the plant, and how plants grow by adding cells until eventually they propagate themselves with remarkable prodigality but without waste, is a matter for study that an almost endless future may never solve.

CHAPTER XVIII

SLEEP

EVERY day must end as it begins, in bed. For centuries poets have praised sleep, but it is only in the last few years that scientists have begun to study its action. We spend one-third of our life in bed. It is obvious that sleep must be of great importance to us. Exactly how and why it is so vital is still a matter of controversy.

Some people seem to need very much less sleep than others. Napoleon, for instance, was said to sleep for only four or five hours a night, while Thomas Edison, the inventor, for sixty years of his long life claimed to average only about four hours of sleep a night, and on occasions managed to carry on successfully with only two hours' sleep. Unfortunately, these figures are not easy to check, for sleep is a most common subject of exaggeration.

Most of us are built differently from these extreme cases, and require not only twice as much sleep, but also sleep at regular intervals. Sleep has come to be recognized as such an important part of our lives that in America lessons in sleeping are part of the curriculum at several universities.

Why do we sleep ? One answer to that question

might be, because without sleep we should die. We should die more quickly from starvation of sleep than from starvation of food, and this has actually been tested experimentally on puppies, who survived for nearly a week without food, but died within three days when denied all sleep. But this does not really answer the question. It would seem obvious that during sleep we rest our bodies. This is perfectly true, but we must do something more, for we all know that lying down without sleeping, even for some time, is not quite the same thing as proper relaxed sleep.

During sleep our rate of breathing diminishes and all the body processes are slowed down so that rest is more complete. Dogs often restrict air to the nose before sleep. But this is not all that happens by closing the eyelids or passing into the unconscious state which we call sleep, because we also appear to rest the brain and mind. The brain is a wonderful and delicate piece of mechanism, and all machines need periodical rest for repairs. Sleep gives the brain its opportunity, although its subconscious department seems still to be active. We may be quite oblivious to people moving about a room, even to light or noise, but the subconscious continues to work and to reveal itself in dreams of which we may have recollection upon waking.

If we accept the theory that we sleep, not so much to rest the body as to rest the mind, several things are explained. For instance, babies not only rest almost continuously, but also sleep almost continu-

ously. The explanation is that coming into a hard and complicated world, which is quite beyond their understanding, babies cannot stand it for more than a few hours at a time and therefore take refuge in sleep. When we grow up, the amount of sleep we need seems to vary. If you are invited to go out to dinner and then to a theatre, or to do something else that is very interesting, you keep awake without feeling very sleepy. If you had stayed at home to read a quiet book, you might very soon have fallen asleep. Reading a rather dull book, in fact, is recommended as a good cure for insomnia. Sleep may, it seems, be almost an escape from boredom, and you will notice how your dog curls himself up for sleep as if he was really very tired, but as soon as you mention the magic word "walk" he pricks up his ears and is ready to start as if sleep was the last thing he needed.

In their endeavour to find out the truth about sleep, scientists have conducted hundreds of interesting experiments. People have volunteered to have themselves examined whilst asleep, and to sleep under all sorts of curious conditions. In America there is what they call a "sleep laboratory" in which all the experiments are conducted upon living people. By using delicate apparatus connected to the sleeper, we have been able to discover the exact effects of light and noise upon a sleeping person. We have also been able to measure rate of breathing and the number of movements made. It has been discovered that, on an average, the ordinary person

moves in his sleep once every twelve minutes. A very ingenious device was arranged so that every time the sleeper moved he took a photograph of himself by working the shutter of a camera focused on the bed.

" Sleeping like a log " is a phrase we use, but it seems to have no actual application in practice. Even in the soundest sleep we move slightly. But it was found that some people moved much more than others, and that those who moved least obtained the most benefit from their sleep. Perhaps this explains why such men as Napoleon and Edison could do with so little rest. They may have been very sound sleepers who obtained far more value from their short sleep than does the average man from what he calls a " good night " of about eight hours.

In the course of these experiments a number of strange things were discovered. It was found, for example, that light is even more disturbing to sleep than noise, and that such a simple thing as light being reflected from a mirror on to the bed could profoundly disturb the sleeper. Curtains, therefore, seem a very necessary part of the furnishing of a bedroom, and the old-fashioned night-light is condemned by science. Noise was also found to be a most disturbing factor, and it is much more difficult to avoid in a bedroom than light. People say they get used to noise, and in large cities like London thousands of people sleep in front rooms with the almost continuous noise of traffic in their ears. Habit enables them to sleep where others might find it

impossible. But this does not mean that their sleep is not disturbed by the noise. The probability is that they require more sleep than if they were in quiet surroundings, for "tiredness" is a kind of poison.

A creaking bed was definitely found to disturb the sleep. Another thing which affected the quality of sleep was the weight of blankets. While cold is an enemy of sleep, a heavy load of blankets is equally to be avoided. It is not necessarily the heaviest blankets that are the warmest, and scientists say that two good blankets are better than four or five of poor type, not only for the warmth they give, but also for the improvement in the quality of sleep.

The effects of not obtaining sufficient sleep were also studied scientifically in the sleep laboratory. The unfortunate volunteers for the test were allowed to have only a few hours' sleep. After this they were awakened and put through a number of tests. In most cases their general ability was lower than when they had had a good night's rest. In some cases, however, the effect of the lack of sleep did not begin to show until some hours afterwards, when concentration began to fail. Put in another way, this means that it is often not until the afternoon that you begin to pay for the late night which you enjoyed eighteen hours before.

In one experiment, a number of people offered to go without sleep altogether for a total period of sixty hours, and throughout this period their reactions, blood pressure, and rate of breathing were

measured regularly. Curiously enough, the mental ability did not greatly deteriorate during this period, but the senses of sight or hearing became less active, and in some cases the volunteers actually began to "see things."

Every man and woman has what is called a reaction time, that is the time that elapses between the brain giving an order and the hand or foot carrying it out. If you are driving a car when a pedestrian suddenly darts into the road in front of you, you may imagine that you apply the brake instantaneously, but, in fact, a definite period of time elapses between the moment when your eyes send the message to the brain and the brain sends it down to your feet. This period may be between one-fifth and a whole second. As you may imagine, it is a very important period. It is often because the boxer or the cricketer has a short reaction period that he is skilful at his sport.

One way of measuring the effects of a lack of sleep is to test the variations in this reaction time. Normally it remains constant for a particular man, but it was found to be lengthened greatly by lack of sleep. A volunteer who had gone without sleep for eighteen or more hours was asked to press a button, which rang a bell, immediately on being given the word of command. A definite period, the reaction time, elapsed between the giving of the word and the pressing of the button. It was found that when he was feeling sleepy the reaction time increased, but that after he had had a sleep of only four hours the reaction time returned to normal. Experiments were

tried with shorter periods of sleep, but four hours was found to be the minimum which could completely restore the normal reaction.

All this is very interesting, it may be said, and it seems an unpleasant affair for the patients to undertake these strange experiments. But it provides useful knowledge. From the last experiment, for example, it may be well deduced that it is highly dangerous to drive a car when feeling sleepy. The danger is not so much that you may actually go to sleep at the wheel, although this has happened, as that you may make an error of judgment which would not occur if you were in a normal state. There have been instances of accidents caused, not only on the road, but also on the railways, due to drivers falling asleep at the "wheel." But more dangerous, because it is less noticeable, is the slowing up of the reaction time. So that an accident, which normally would have easily been averted, is caused by just that little difference of perhaps one-fifth of a second —the time in which a car travelling at sixty miles an hour will move over seventeen feet.

Then again, all these experiments were devoted not only to the discovery of theoretical knowledge about sleep, but in learning actually how to apply it to practice. It was definitely found that the benefit derived from a night's rest depended not only upon the length of time spent in sleep, but upon what may be called the quality of that sleep. Sleep on a good mattress, neither too hard nor too soft, with light bedclothes in a quiet and dark room, was seen to be

very much more effective in restoring the vigour of the brain than sleep in poor conditions. In other words, the man who slept properly did not need to sleep nearly so long.

In view of the fact that we spend quite one-third of our life in bed, this is most important. Considering the efforts that have been made by economists, politicians, and scientists to reduce the length of the working week so that a man has each day an average of eight hours' work and eight hours' leisure, it is surprising that no attempt has been made to reduce the length of the night. If we could take just one hour from our sleep every night without in any way affecting the benefits we receive from it, that would mean we had seven hours each week more for play. We should have one whole day more every month, twelve days more every year—nearly the equal of a yearly holiday.

No suggestion is made that any one should spend less time in bed; it is merely pointed out that if science could show us how to reduce our average sleep from, say, eight hours to seven hours without in any way affecting the benefits it would have performed a tremendous service. We have not quite reached this stage yet, but further tests may enable us to do so, and confer a benefit equal to that of great labour-saving inventions which have made possible a shorter working week as well as a better standard of living. We cannot always sleep without dreaming, and dreams, too, have greatly attracted the scientists. Many theories have been put forward about dreams,

but it seems, probably, that they are mainly due to mixed and recurrent or even hereditary memories.

One of the most remarkable things about sleep is that it may occasionally solve our troubles in thought. "Sleep on it," is an old piece of advice, and science has shown that it is often quite sound. During sleep, although the active brain is resting, the inactive or subconscious brain continues to work and perhaps to deal with the difficult problem we have had to face. Many great inventions have been made during sleep. Some time ago Professor Boys related how he saw in a dream a new instrument for measuring the value of gas used for public consumption. He jumped out of bed, rushed into his laboratory and began to make the machine he had seen. Of course this was not an inspiration that had come from an outside source. Professor Boys must have had the machine in his mind, and his subconscious had to wait until sleep dulled the conscious mind before being able to thrust it forward.

Many other similar examples have been quoted, and on one occasion a very difficult problem in archæology was solved by a dream. The sleeper dreamt that a priest dressed in ancient garb came to him and gave him the necessary clue to enable him to read an ancient inscription. Here again we should not be prepared to believe that anything occult occurred, but that the archæologist had really solved his problem without knowing it, and that it required sleep to enable him to visualize it more clearly. The inventor of that mathematical system known as

the differential calculus is stated, in the same way, to have received his final " inspiration " in a dream.

In the nature of things, dreams are difficult to study because we can only truthfully know our own dreams, and we forget these very, very quickly. If you try to recollect the vivid dream you had the night before, on the following evening, you will often fail and wonder how on earth so strange a mixture of disconnected events could have frightened or interested you. J. W. Dunne has suggested a very interesting theory about dreams. Put very simply, it means that every dream is a mixture of the past, present, and future, and that this explains why dreams sometimes come true. Dunne's theory is not mere fantasy, but is supported by reasoning and calculation upon which is based a whole theory of time. It is worthy of careful study ; although scarcely likely to result in a dream of the Derby winner, it is at least a step towards that happy day when the facts of time or space will prove less mysterious and much more useful.

Never try to go to sleep. Try to feel sleepy. It is easier to study a known experience than delve into yet another of the many problems which science has still to solve.

CONCLUSION

SCIENCE has only made its beginning in domestic life. The homes of the future will see changes more complete than any that we imagine. 'For this reason alone it is necessary that we should prepare ourselves lest those who follow may suffer from the prejudice that is apparently excited by all progress.

It is no exaggeration to suggest that we are now little better than savages in relation to the world of a few centuries hence, and that the public will enjoy, eventually, a degree of luxury which would be fantastic, or even distressing, to our undeveloped minds.

Electric power is man's greatest friend. By its aid the word "impossible" can be blotted out. Power may be broadcast, communication across the world will alter our outlook until our own problems of food, heating, lighting, health, and even peace may be solved.

To-day we do not know how it is that light is given to us as a human sensation by the motion of æther between the Sun and our Earth. We try to discover how conducting wires can be made invisible to enemy aeroplanes; we wonder if a few sheets of dry paper are an adequate protection against a badly earthed broadcast receiver; we pay 90 per cent.

to gain 10, in most cases, when energy has to be transformed.

But our attempts will not be wasted. Homes of the future will easily avoid every discomfort that we suffer to-day. Perhaps a little love for nature or science may teach us to overcome those difficulties which we do not yet need to face.

Two hundred years ago we lived in filth. We are a little better to-day. But we wait for pocket radio, silent electrical aeroplanes, better clothing, and the innumerable time-saving inventions that change will bring.

And so to bed, where we can remember that time, the only reality in this changing world, has little meaning; to a land where dreams move backwards or forwards without control; where there only remains that permanency of thought with which we may have to deal in every future scientific home.

Hartland, 1938.

THE END

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